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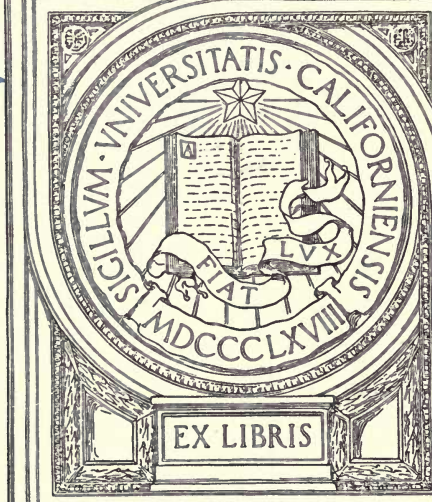
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TESTS ON THE HOLDING POWER OF RAILROAD SPIKES

By Albin H. Beyer and
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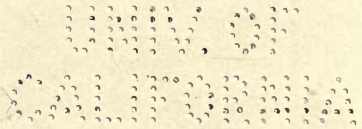
SEPTEMBER, 1919

Tests on the Holding Power of Railroad Spikes

By Albin H. Beyer and
William J. Krefeld

BULLETIN No. I

DEPARTMENT OF CIVIL ENGINEERING



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BULLETIN NO. 1 SEPTEMBER, 1919

TESTS ON THE HOLDING POWER OF RAILROAD SPIKES

By ALBIN H. BEYER, *Associate in Civil Engineering*
and
WILLIAM J. KREFELD, *Instructor of Civil Engineering*

This paper describes a series of experiments made on the holding power of certain railroad spikes under varying conditions and in different kinds of ties.

A limited investigation made at the Laboratories at the request of the American Spike Company of New York City, to determine the holding power of a new design of spike, was enlarged to include also a standard cut and a standard screw spike for purposes of direct comparison. The data secured is of sufficient general scientific interest to the profession as a whole to warrant its publication.

The behavior of these three types of spikes was investigated for:

1. Resistance to direct pull;
2. Resistance to direct pull as affected by redriving.

TYPES OF SPIKES

Three different kinds of spikes were tested:

(*a*) Cut spike, chisel-pointed, marked 1P to 20P, furnished by the Pennsylvania Lines, West. This type of spike was selected in preference to the type of spike submitted by the New York Central Railroad because it was ½-inch longer, namely, 6 inches under the head, thus allowing a 5½-inch insertion into the tie, leaving ½-inch under the head when no tie plate is used. Average weight, 0.81 lbs. per spike.

(*b*) Screw spike, marked 1S to 17S; standard screw spike submitted by the Delaware, Lackawanna & Western Railroad. Average weight, 1.31 lbs. per spike.

(*c*) Sessler Grip spike, marked 1G to 16G; a new type of spike submitted by the American Spike Company of New York City. This spike was turned and milled from steel bars and then heated in a gas furnace to produce a surface scale similar to that of the commercial product. Average weight, 1.10 lbs. per spike.

M226312

The dimensions and details of the various spikes are given in Plate I., Plate II, is a photograph of the three types of spikes tested.

The physical properties in tension of the material forming the spikes tested have been determined and are as follows (standard navy test specimens machined from the finished spike):

TABLE I

Physical Properties of Material in Spikes

	Cut Spike	Screw Spike	Sessler Grip Spike
Yield point—lbs. per sq. in.	52,300	42,400	43,300
Ultimate tensile strength—lbs. per sq. in.	63,200	58,800	63,400
Percentage of elongation in 2 inches	36.5	25.0	34.5
Percentage reduction in area	68.1	64.9	65.9

TIES

The ties used in these tests were submitted gratuitously from stock by the various railroads and represent average quality. The description of these ties is given in Table II.

TABLE II

Description of Ties

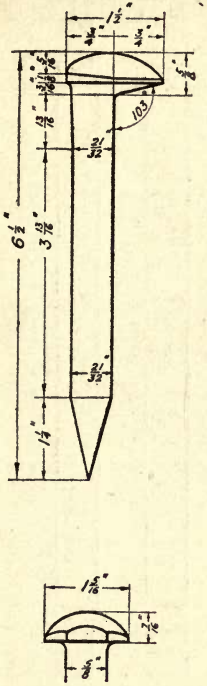
No.	Timber	Form	Treatment	Received From	Condition
1	Chestnut	Sawed two sides	Untreated	N. Y. C. R. R.	Surface checked
2	Chestnut	Sawed two sides	Untreated	N. Y. C. R. R.	Knotty
3	Chestnut	Sawed two sides	Untreated	N. Y. C. R. R.	Badly checked
4	Yellow Pine	Sawed two sides	Creosoted	N. Y. C. R. R.	Good
5	Yellow Pine	Sawed two sides	Creosoted	N. Y. C. R. R.	Surface checked
6	Yellow Pine	Sawed two sides	Creosoted	N. Y. C. R. R.	Badly checked
7	White Oak	Sawed two sides	Untreated	N. Y. C. R. R.	Slight surface checks —dead wood
8	White Oak	Sawed two sides	Untreated	N. Y. C. R. R.	Surface checked
9	White Oak	Sawed two sides	Untreated	D. L. & W. R. R.	Very good
10	Douglas Fir	Sawed four sides	Untreated	Erie R. R.	Knotty
11	Douglas Fir	Sawed four sides	Untreated	Erie R. R.	Surface checked
12	White Oak	Hewn	Untreated	D. L. & W. R. R.	Surface checked
13	Douglas Fir	Sawed four sides	Untreated	Erie R. R.	Surface checked

DIRECT PULLING TESTS

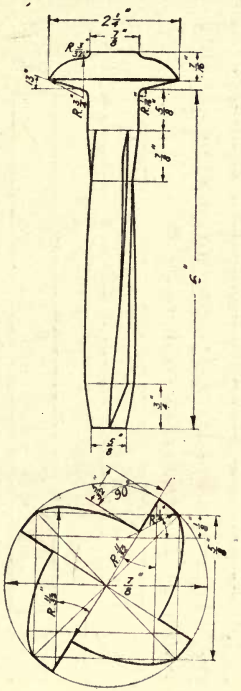
Direct pulling tests were made to determine the holding power of the three kinds of spikes described, in each of the four kinds of ties, under the following conditions:

PLATE I

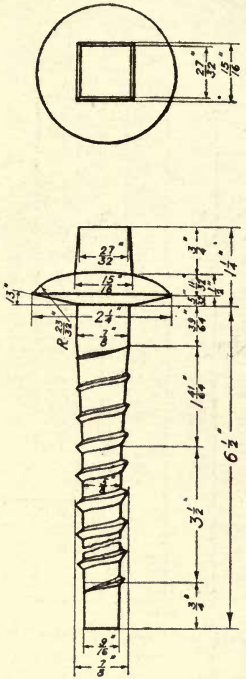
DETAILS AND DIMENSIONS OF SPIKES TESTED



Standard Cut Spike, Pennsylvania R.R. Lines West



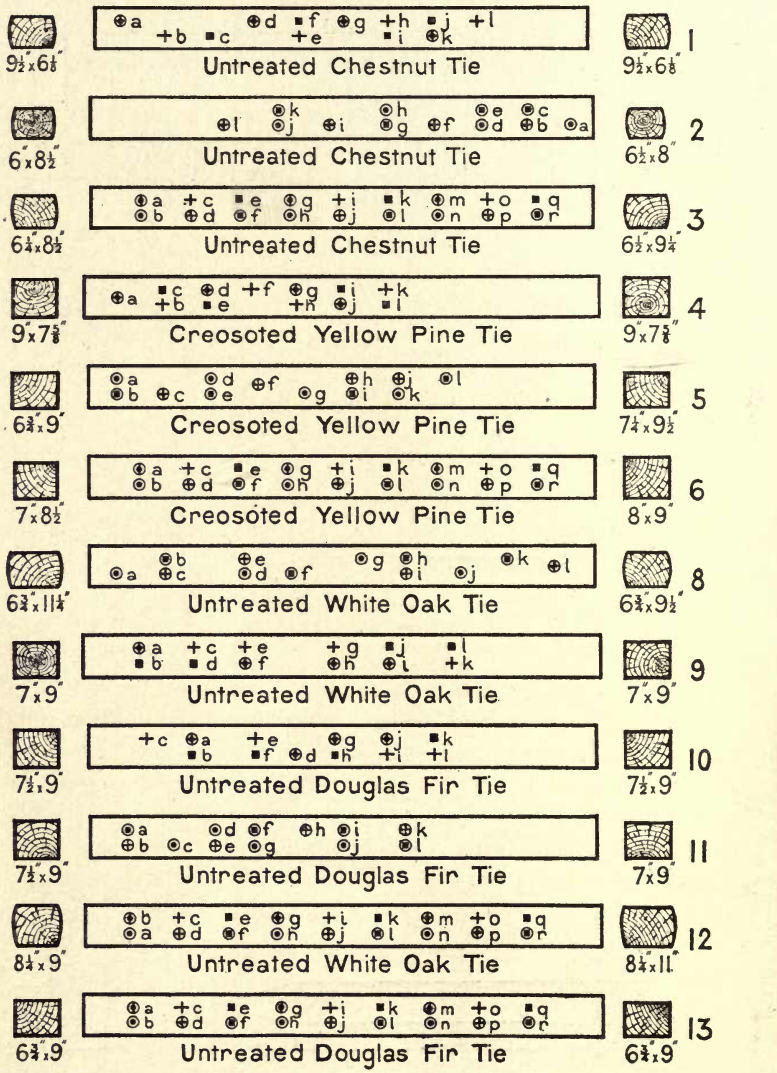
Sessler Grip Spike



Delaware, Lackawanna & Western R.R. Screw Spike

PLATE III

Diagrammatic Plan showing Location of Spikes Tested



Cut Spike
No hole.....■
½" hole.....⊙

Screw Spike
Screwed 6".....⊙
Driven 4½"-Screwed 1½".....⊕
Driven all the way.....⊕

Sessler Grip Spike
No hole.....+
⅛" hole.....⊕

(*a*) 4 Pennsylvania cut spikes driven 5½ inches without bored hole;
(*b*) 4 Pennsylvania cut spikes driven 5½ inches into ½-inch bored hole;
(*c*) 4 D. L. & W. screw spikes screwed 6 inches into 5-8-inch hole;
(*d*) 4 D. L. & W. screw spikes driven 6 inches into 5-8-inch hole;
(*e*) 4 Sessler Grip spikes driven 5½ inches without bored hole;
(*f*) 4 Sessler Grip spikes driven 5½ inches into 7-16-inch bored hole.

All cut and Sessler Grip spikes were driven by a man inexperienced in track work. The screw spikes were inserted in accordance with the personal instructions of Mr. Medill, Roadmaster of the D. L. & W. Railroad Terminal at Hoboken, N. J.

The spikes were driven into the ties in pairs, directly opposite each other, and spaced about ten inches apart along the tie. Four spikes of each type, making a total of twelve spikes per tie, comprised one set. Care was taken in driving to avoid checks and knots. The location of the spikes in the ties, as well as the dimensions of the ties, are shown diagrammatically in Plate III.

All preformed holes were made by means of a drill press, thus insuring straight alignment. The sizes of the preformed holes used in this investigation were:

(*a*) Pennsylvania cut spike (Lines West), ½-inch, giving a drift of 1-8-inch;
(*b*) D. L. & W. screw spike, 5-8-inch, in accordance with the standard practice of the road;
(*c*) Sessler Grip spike, 7-16-inch, in accordance with the recommendation of the American Spike Company, giving a drift of 1-8-inch on shank.

One set of screw spikes in each kind of tie was driven for the full 6-inch depth to determine also the effect upon the holding power of driving as compared with the standard method of screwing the spike in.

Attention is here called to the fact that the total penetration of both the cut spike and the Sessler Grip spike was 5½ inches as compared to 6 inches for the screw spike. The results, therefore, give the comparative holding power for the spikes as used without regard to effects produced by differences in depth of penetration and size of prebored holes.

METHOD OF TESTS

All tests were made in the Civil Engineeering Testing Laboratory at Columbia University.

The tie, with the spikes to be tested facing downward, rested upon two steel blocks upon the upper head of a 100,000-lb. Riehle

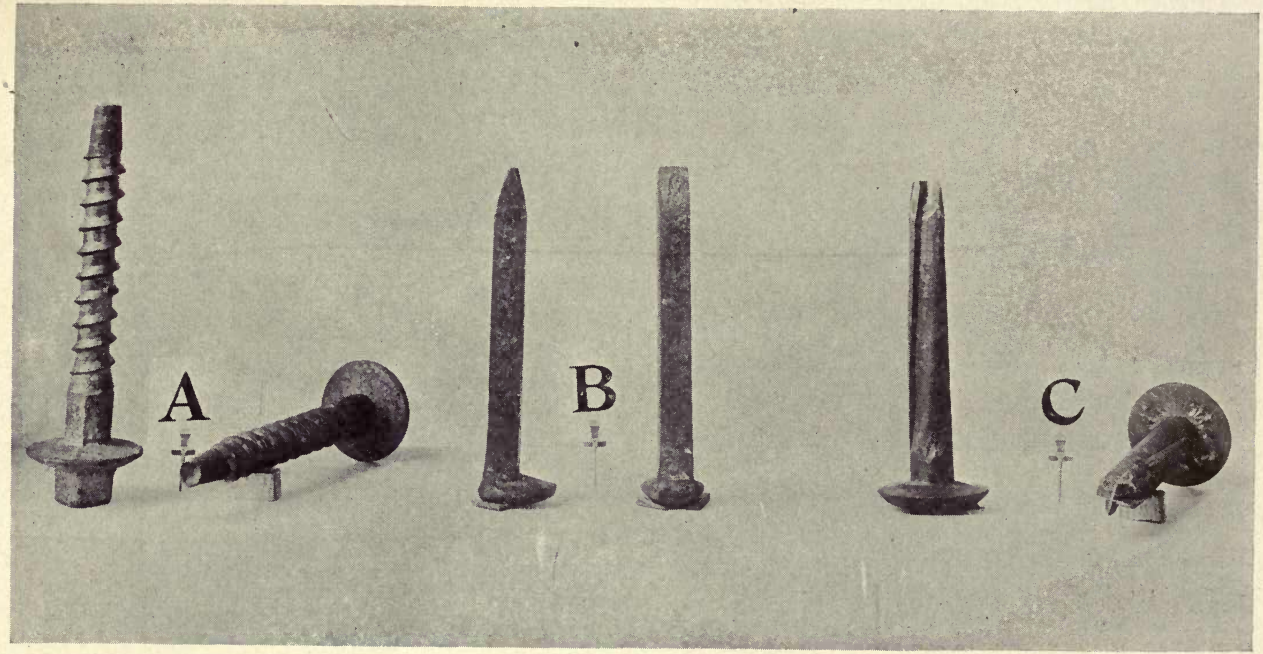
testing machine. The spike was gripped by means of a special holder forged in the form of a closed yoke and provided with a slot of width just sufficient to engage the shank of the spike below the head. The same holder was used for the screw and Sessler Grip spikes as they had the same sized shank under the head. The holder used for the cut spike was similar except for the slot, which was slightly narrower. The load, therefore, was applied to the spike head at two points directly opposite each other, thus tending to insure an axial pull. The lower ends, or shanks, of these holders were held by the pin of a shackle which was in turn held by a yoke gripped by the wedges in the lower head of the testing machine.

The actual withdrawal of the spike was measured to the 1–1,000 part of an inch by means of a deflectometer of the lever type, one end of which was placed directly in contact with the head of the spike. Very large errors resulting from the play in the bearings of the holder, deformation of the holder proper, slippage of the holder in the wedges, and withdrawal of the wedges from the lower cross-head as they tighten on the shank of the holder, which are introduced when the withdrawal is measured by the movement of the lower cross-head of the testing machine, as has been done in many previous experiments, were thereby eliminated. This method does not however, eliminate errors due to the compression of the wood on the cast iron bearing blocks and the twisting of the tie, especially one having a rough or warped bearing surface in contact with the bearing blocks, as the load on the spike increases.

In planning these tests it had been assumed, based upon the results of previous experiments, that the displacements to be measured would be of such magnitude that the above errors would have no appreciable influence upon the results. When, however, the data secured in these tests was digested it was found that the entire phenomena of elastic stress and strain, including incipient failure, took place at withdrawals of .05 of an inch and less. Subsequent tests of limited extent were then made with an Ames dial recording the withdrawal of the spike directly to 1–10,000 part of an inch, to determine the true elastic behavior and stress strain relation of the various spikes.

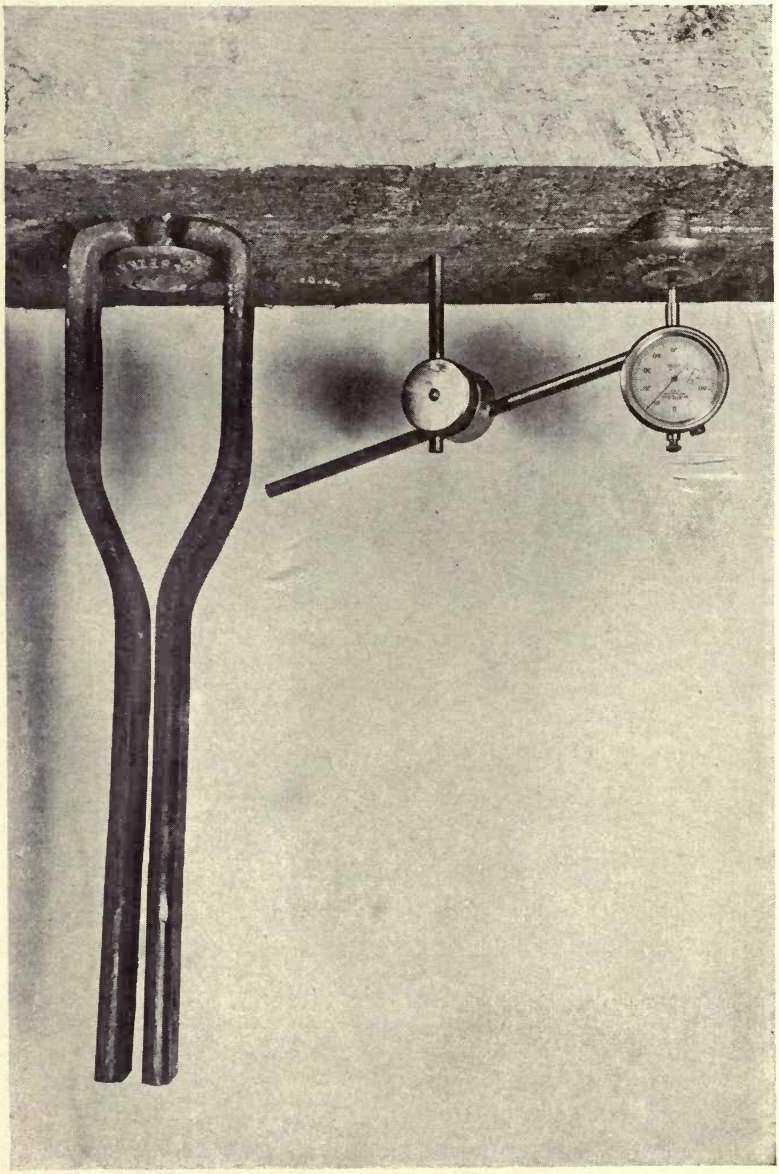
Tests were also made to determine the accuracy of measuring the displacement of the spike by recording it simultaneously by three different methods, as follows:

PLATE II



A. Standard Screw Spike, Delaware, Lackawanna and Western R. R.
B. Standard Cut Spike, Pennsylvania Lines West
C. Sessler Grip Spike, American Spike R. R. Company, New York City

PLATE IV



Ames Dial Measuring Apparatus and Holder for Pulling Spikes

First: Recording the displacement of the lower cross-head—the usual method employed in previous experiments.

Second: Recording the displacement of the head of the spike by means of a deflectometer resting directly upon the upper head of the testing machine—the method largely used in this investigation.

Third: Recording the displacement by means of an Ames dial attached directly to the tie.

Plate IV shows the mounting of the Ames dial as well as the holder used for pulling the spikes. The third method of measuring the withdrawal eliminated all sources of error except instrumental. The dial was calibrated by means of a special micrometer reading directly to 1–100,000 part of an inch and was found to be reliable to 1–10,000 part of an inch.

Plate V shows the errors that are introduced when the first and second methods of measuring the withdrawal are used. The first method, heretofore used in many tests, gives withdrawals so greatly in excess of the actual displacements that the results can have but little scientific value.

Plate VI shows the tie to be tested, second method, in position in the testing machine with the deflectometer in place. To properly seat the tie upon the bearing blocks, an initial load of 500 lbs. was applied and the deflectometer was adjusted to read zero. The load was increased with the lower head moving practically continuously at the rate of 0.06 of an inch per minute, and the withdrawal of the spike was read upon the deflectometer for each increment in load of 500 lbs. until the maximum resistance was reached. Thereafter loads were recorded for each 0.05 of an inch withdrawal, unless the behavior of the spike warranted taking additional readings and until a total withdrawal of 0.475 of an inch was obtained, beyond which the information would be of minor importance.

RESULTS OF PULLING TESTS

The results obtained from the tests made upon the four spikes of one type in each kind of tie were averaged and these average results plotted.

Tables III to X are the detailed log sheets of the tests. For purposes of comparison and for the computation of the average curve, the resistances of the spikes are tabulated for definite amounts of withdrawals. In many instances this data was not recorded

PLATE V

Diagram showing the relative accuracy of the various methods of measuring the withdrawal of a spike
Withdrawals of a screw spike in a white oak tie measured simultaneously by the three methods

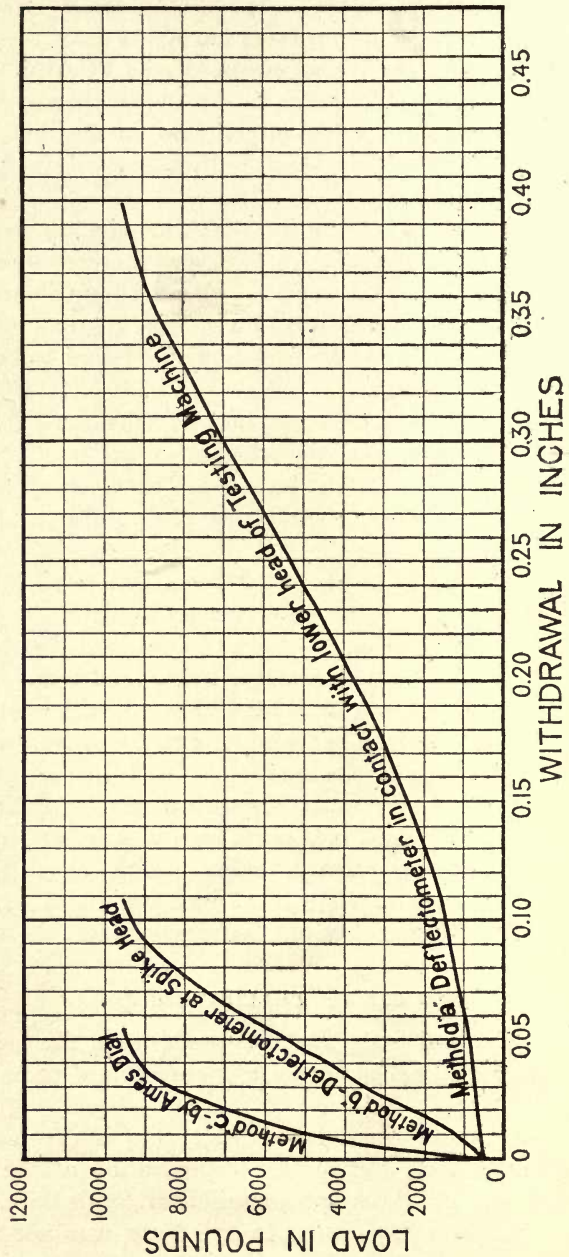
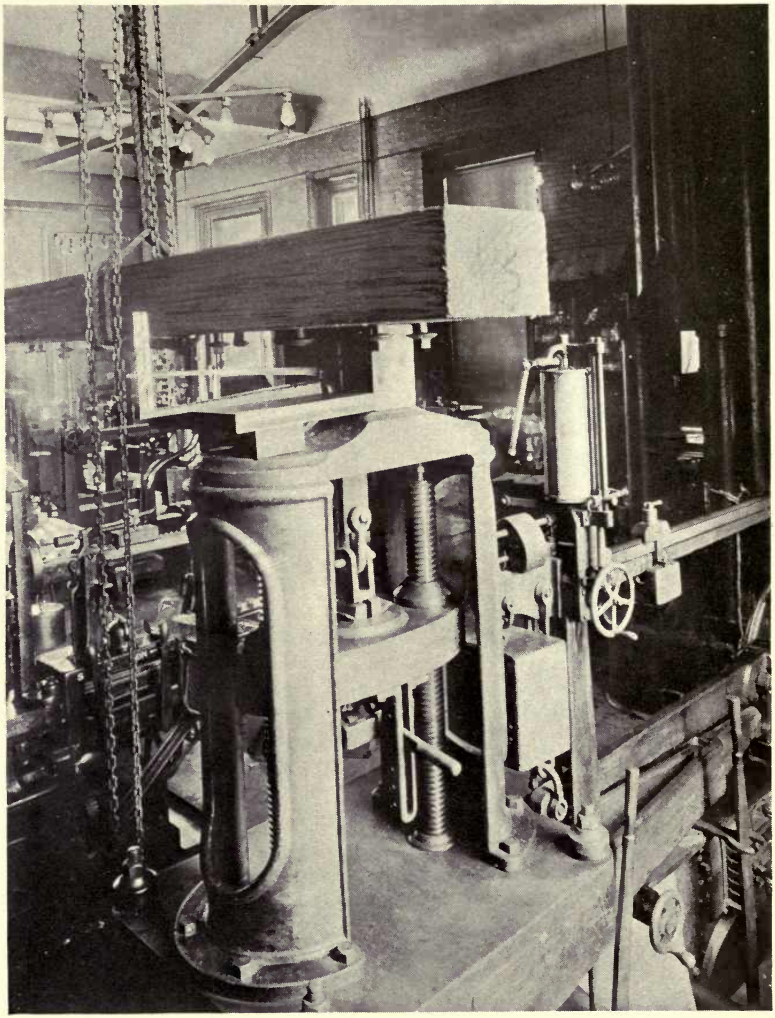


PLATE VI



Tie in Position in Testing Machine

Results of Direct Pull Tests

PLATE VII

DIRECT PULL TESTS

Untreated Chestnut Tie No. 1

Pennsylvania Cut Spike—Driven 5½ Inches, No Hole
D. L. & W. Screw Spike—Driven 6 inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½-inches, No Hole

To Accompauy Table III

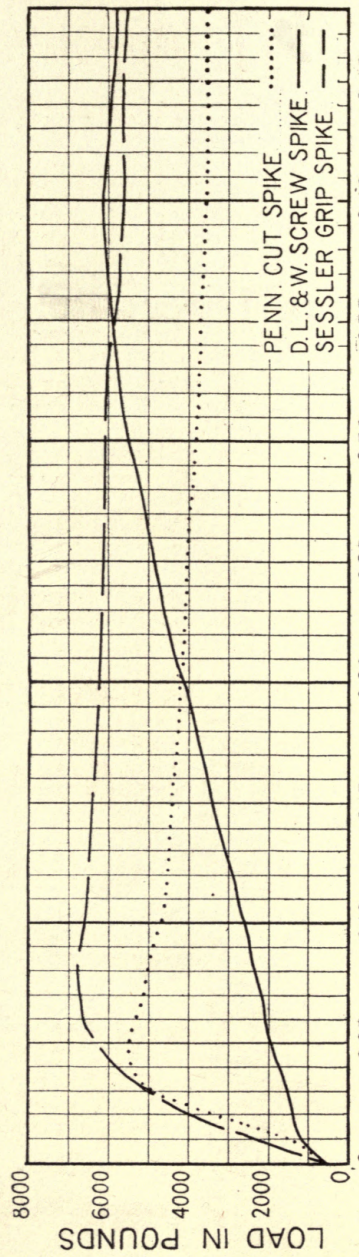


TABLE III

DIRECT PULL TESTS. UNTREATED CHESTNUT TIE. NO. 1

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches No Hole					D. L. & W. Screw 6 Inches Driven into ⅝-inch Hole					Sessler Grip 5½ Inches No Hole				
Laboratory Number	7656	7657	7658	7659		7660	7661	7662	7663		7664	7665	7666	7667	
Withdrawal Inches	17 P at j	18 P at i *	19 P at f	20 P at c	Average	15 S at k	16 S at g	17 S at d	18 S at a	Average	13 G at 1	14 G at h	15 G at e	16 G at b	Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	2000	2180	1500	1000	1500	1080	1500	1140	870	1150	3000	2000	1880	1700	2140
.020	4100	4500	3500	2200	3270	1220	1690	1400	1120	1380	4940	4000	3500	3000	3860
.030	5910	6650	5270	3600	4930	1380	1880	1600	1310	1540	5520	5000	5250	4200	4990
.040	6040	8080	5980	4600	5540	1570	2050	1760	1450	1710	6000	5590	6550	5020	5790
.050	5860	8830	5830	5000	5560	1720	2300	1900	1580	1880	6290	5900	7200	5670	6260
.060	5500	8900	5650	4980	5380	1860	2520	2050	1700	2030	6520	6100	7660	5930	6550
.070	5180	8540	5410	4900	5160	2010	2700	2160	1800	2170	6620	6230	7960	6100	6730
.080	5030	8200	5250	4750	5010	2200	2900	2300	1940	2330	6560	6350	8000	6220	6780
.090	4930	7800	5080	4550	4850	2330	3070	2500	2100	2500	6440	6430	7940	6030	6710
.100	4860	7400	4920	4380	4720	2470	3240	2610	2260	2650	6350	6440	7840	5870	6620
.150	4580	6840	4620	4090	4430	3240	4240	3360	2840	3420	6320	6520	7340	5650	6460
.200	4360	6570	4370	3030	4220	4000	5100	3950	3420	4120	6280	6280	7030	5440	6260
.250	4200	6320	4170	3720	4030	4800	5980	4670	4130	4890	6210	6140	6800	5220	6090
.300	4020	6090	4020	3530	3860	5500	6680	5090	4650	5480	6080	6030	6610	5080	5950
.350	3890	5980	3910	3460	3750	6000	7030	5460	5100	5900	5960	5930	6440	4910	5810
.400	3820	5840	3790	3360	3660	6360	6840	5800	5530	6130	5840	5880	6280	4770	5690
.450	3680	5700	3640	3280	3530	6130	6520	5740	5370	5940	5760	5810	6200	4670	5610
.475	3630	5640	3620	3250	3500	5980	6320	5650	5160	5780	5700	5750	6140	4550	5530
Maximum load	6040	8900	6000	5000	5680	6360	7070	5930	5540	6220	6620	6520	8000	6220	6840
Withdrawal	.042	.060	.037	.044	.041	.400	.393	.425	.425	.404	.073	.120	.076	.085	.089

* Driven through knot—not included in average.

PLATE VIII

DIRECT PULL TESTS

Untreated Chestnut Tie No. 2

Pennsylvania Cut Spike—Driven 5½ Inches into ½-inch Hole
D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½ Inches into ⅛-inch Hole

To Accompany Table IV

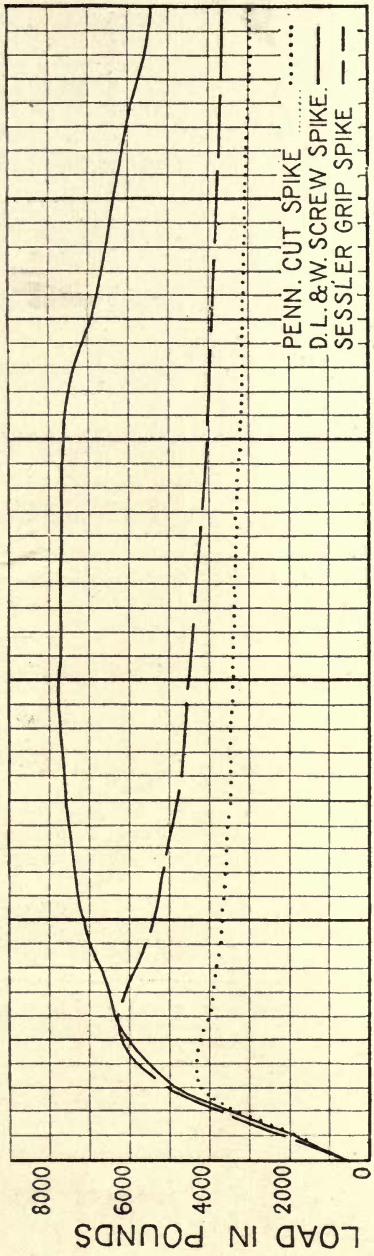


TABLE IV

DIRECT PULL TESTS. UNTREATED CHESTNUT TIE. NO. 2

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches Into ½-inch Hole					D. L. & W. Screw 6 Inches Screwed into 5/8-inch Hole					Sessler Grip 5½ Inches Into 7/16-inch Hole				
Laboratory Number	7668	7669	7670	7671		7672	7673	7674	7675		7676	7677	7678	7679	
Withdrawal Inches	7 P at c	8 P at e	9 P at g	10 P at k	Average	7 S at a *	8 S at d	9 S at h	10 S at j	Average	1 G at b	2 G at f	3 G at i	4 G at 1	Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	1700	1600	2500	1650	1880	1600	2000	2000	1900	1970	1900	2400	2400	2000	2180
.020	3100	3300	3760	3250	3350	3000	3650	3600	3450	3570	3500	4350	3500	3900	3810
.030	4200	4040	4480	3960	4170	4200	5030	4930	4430	4800	4900	5750	4470	5250	5090
.040	4490	4150	4460	3900	4250	5630	6070	5510	5000	5530	5630	6630	5480	5990	5930
.050	4300	4130	4430	3830	4170	7000	6700	5850	5300	5950	6000	6790	6000	5970	6190
.060	4050	3900	4330	3710	4000	7900	7020	6140	5620	6260	5940	6800	6250	5830	6200
.070	4050	3720	4200	3600	3890	8500	7280	6500	5920	6570	5850	6400	6150	5670	6020
.080	4050	3610	4110	3470	3810	9000	7500	6700	6150	6780	5740	6080	5920	5520	5810
.090	3950	3580	4080	3420	3760	9370	7730	6860	6380	6990	5640	5890	5550	5420	5620
.100	3820	3550	4020	3390	3700	9640	7900	7000	6500	7130	5500	5760	5160	5310	5430
.150	3690	3300	3820	3250	3520	10580	8330	7550	7030	7630	4870	5240	4500	4730	4830
.200	3720	3210	3720	3080	3430	11110	8350	7760	7440	7850	4520	5030	4170	4330	4510
.250	3490	3220	3630	2970	3330	11270	8450	7560	7340	7780	4330	4660	4000	4000	4250
.300	3420	2930	3500	2890	3190	10930	8270	7270	7330	7620	4280	4480	3890	3760	4100
.350	3350	2830	3450	2790	3110	10550	7920	6580	7180	7230	4280	4280	3770	3570	3970
.400	3300	2760	3340	2720	3030	10120	7060	5720	6260	6350	4130	4080	3650	3420	3820
.450	3220	2690	3260	2660	2960	9510	6420	5260	5560	5750	4010	3900	3580	3310	3700
.475	3180	2630	3240	2630	2920	9190	6050	5050	5230	5440	3950	3810	3550	3260	3640
Maximum load	4500	4170	4500	4000	4290	11290	8520	7760	7460	7910	6000	6830	6240	6000	6270
Withdrawal	.038	.048	.026	.026	.035	.241	.275	.200	.275	.250	.048	.058	.063	.041	.052

* Driven through knot—not included in average.

PLATE IX

DIRECT PULL TESTS

Treated Yellow Pine Tie No. 4

Pennsylvania Cut Spike—Driven 5½ Inches, No Hole
D. L. & W. Screw Spike—Driven 6 Inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table V

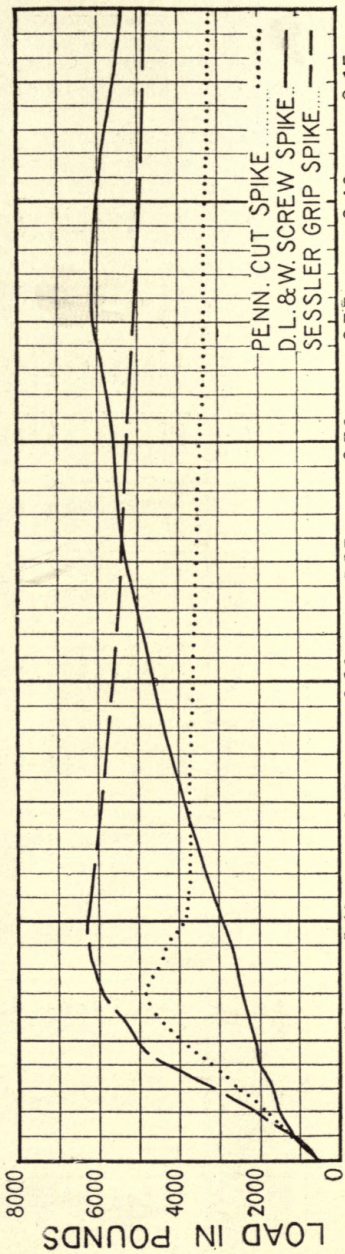


TABLE V

DIRECT PULL TESTS. TREATED YELOW PINE TIE. NO. 4

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches No Hole					D. L. & W. Screw 6 Inches Driven into ⅝-inch Hole					Sessler Grip 5½ Inches No Hole				
Laboratory Number	7680	7681	7682	7683		7684	7685	7686	7687		7688	7689	7690	7691	
Withdrawal Inches	13 P at 1	14 P at i	15 P at e	16 P at c	Average	11 S at j	12 S at g	13 S at d	14 S at a	Average	9 G at f	10 G at k	11 G at h	12 G at b	Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	1620	1500	1210	700	1260	1350	1230	970	1000	1140	1100	1100	1200	1000	1100
.020	2420	2150	2040	920	1880	1900	1600	1400	1490	1600	2500	1880	1930	2000	2080
.030	3190	3000	2820	1180	2550	2200	1830	1650	1190	1720	3800	2600	2530	3500	3110
.040	4020	3700	3500	1450	3170	2380	2000	1810	1840	2010	4890	3480	3500	5140	4240
.050	5000	4540	4450	1800	3950	2500	2130	1950	2000	2140	5460	4000	4400	6260	5030
.060	5500	5500	4690	2550	4560	2680	2300	2070	2120	2290	5480	4500	5000	6920	5480
.070	5060	5990	4870	3350	4820	2850	2470	2240	2270	2460	5350	5340	5800	7180	5920
.080	4700	4650	4970	4000	4580	3050	2670	2410	2400	2630	5120	5980	6020	7300	6120
.090	4350	3240	4800	4600	4250	3300	2830	2540	2500	2790	4900	6490	6030	7400	6220
.100	4000	2410	4400	4700	3890	3500	3000	2670	2600	2940	4700	6900	6040	7430	6270
.150	3880	4210	3270	3540	3780	4500	4140	3430	3350	3850	4380	6930	5530	6840	5920
.200	3830	4240	3160	3360	3650	5320	5100	4000	4130	4640	4270	6580	5330	6590	5690
.250	3750	4170	3050	3140	3530	6130	5910	4550	4860	5360	4120	6250	5220	6240	5460
.300	3670	4060	2980	3060	3440	6910	6350	4990	5410	5920	4120	6010	5140	5940	5300
.350	3580	3970	2920	2920	3350	7220	6410	5080	5730	6110	4120	5800	5080	5560	5140
.400	3520	3900	2810	2840	3270	7290	6160	4960	5720	6030	4030	5640	5030	5320	5010
.450	3460	3820	2750	2780	3200	6860	5800	4880	5150	5670	3960	5540	5020	5040	4890
.475	3460	3740	2680	2750	3160	6580	5560	4710	4900	5440	3880	5500	5020	4960	4840
Maximum load	5500	6000	5000	4700	5300	7290	6490	5080	5750	6150	5500	7000	6040	7430	6490
Withdrawal	.060	.069	.083	.100	.078	.373	.342	.350	.397	.366	.052	.107	.100	.100	.090

PLATE X

DIRECT PULL TESTS

Treated Yellow Pine Tie No. 5

Pennsylvania Cut Spike—Driven 5½ Inches into ½-inch Hole
D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½ Inches into ⅞-inch Hole

To Accompany Table VI

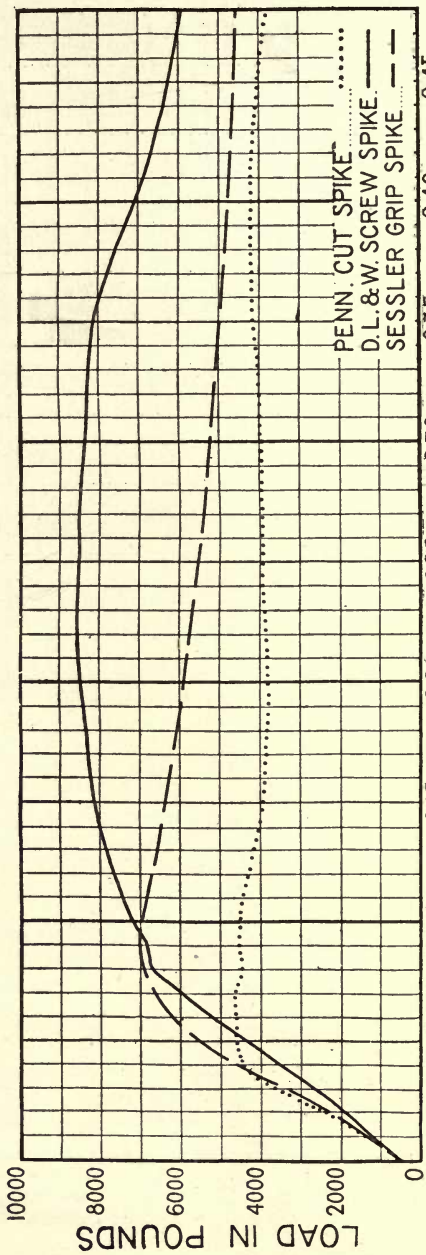


TABLE VI

DIRECT PULL TESTS. TREATED YELLOW PINE TIE. NO. 5

Resistance in Pounds

Type of Spike:	Pennsylvania Cut					D. L. & W. Screw					Sessler Grip				
Depth of Penetra'n:	5½ Inches					6 Inches					5½ Inches				
Method of Driving:	Into ½-inch Hole					Screwed into ⅝-inch Hole					Into $\frac{1}{16}$-inch Hole				
Laboratory Number	7692	7693	7694	7695		7696	7697	7698	7699		7700	7701	7702	7703	
Withdrawal Inches	5 P at b	6 P at c	7 P at i	8 P at e	Average	1 S at a	7 S at d	8 S at g	9 S at k*	Average	5 G at c	6 G at f	7 G at h	8 G at j	Averag
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	1030	1500	1400	1360	1320	980	1000	1750	1250	1240	1700	1500	980	1250	1360
.020	1700	2800	2400	2500	2350	1300	1630	3000	1800	1980	3050	2500	1500	2000	2260
.030	2650	4250	3500	4000	3600	1700	2540	4000	2400	2750	4500	3550	2450	3120	3410
.040	3550	4900	4500	4980	4480	2100	3660	4780	3030	3510	5550	4670	3500	4350	4520
.050	4450	4650	4240	5180	4630	2520	5000	5630	4050	4380	6500	5450	4570	5500	5510
.060	4560	4570	3940	5320	4600	3000	6050	6500	5000	5180	7000	5900	5540	6350	6200
.070	4620	4480	3900	5460	4620	3490	6900	7270	6050	5890	7420	6200	6360	6800	6690
.080	4660	4420	4070	4950	4500	3780	7580	7860	7000	6410	7620	6240	6740	7240	6960
.090	4680	4390	4100	4970	4540	4100	8100	8230	8000	6810	7500	6250	6940	7510	7050
.100	4700	4360	3970	4990	4510	4310	8530	8600	8650	7150	7360	6260	6800	7590	7000
.150	3430	4030	3520	4700	3920	5290	9500	9600	10620	8130	6500	5510	6570	6920	6380
.200	3770	3830	3200	4410	3800	5520	9940	10050	11470	8500	6000	5090	6150	6520	5940
.250	3810	3660	3230	5000	3930	5350	9920	10160	11780	8480	5580	4730	5700	6140	5540
.300	3680	3500	3400	5220	3950	5200	9630	10250	11580	8360	5220	4320	5440	5900	5220
.350	3560	3390	3450	6330	4180	4840	9030	9690	11100	7850	4990	4050	5220	5720	5000
.400	3520	3310	3390	6670	4220	4390	8090	8820	9980	7100	4670	3810	5050	5550	4770
.450	3440	3180	3340	6220	4050	3990	7060	7850	8760	6300	4450	3620	4990	5420	4620
.475	3330	3100	3200	5400	3760	3790	6400	7500	8140	5900	4330	3570	4860	5340	4530
Maximum load	4700	5000	4500	6760	5240	5540	9990	10360	11780	8630	7620	6260	6940	7620	7110
Withdrawal	.100	.034	.040	.375	.137	.225	.217	.290	.250	.244	.080	.100	.090	.103	.093

* Driven through knot, not used in average.

PLATE XI

DIRECT PULL TESTS

Untreated White Oak Tie No. 8
Pennsylvania Cut Spike—Driven into ½-inch Hole
D. L. & W. Screw Spike—Screwed into ⅝-inch Hole
Sessler Grip Spike—Driven into ¹⁄₁₆-inch Hole
To Accompany Table VII

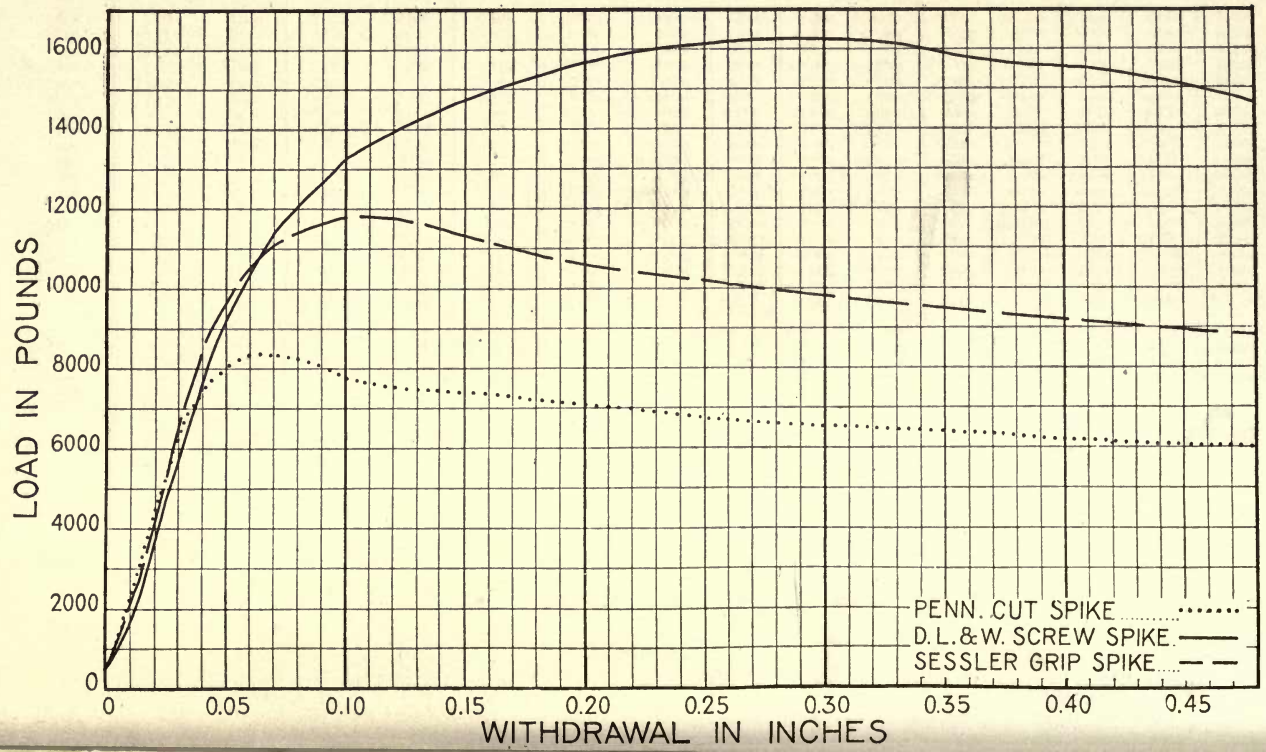


TABLE VII

DIRECT PULL TESTS. UNTREATED WHITE OAK TIE. NO. 8

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches Into ½-inch Hole					D. L. & W. Screw 6 Inches Screwed into ⅝-inch Hole					Sessler Grip 5½ Inches Into 7/16-inch Hole				
Laboratory Number	7716	7717	7718	7719		7720	7721	7722	7723		7724	7725	7726	7727	
Withdrawal Inches	9 P at k	10 P at h	11 P at f	12 P at b	Average	15 S at j	16 S at g	17 S at d	18 S at a	Average	5 G at 1	6 G at i	7 G at e	16 G at c	Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	1000	3000	2500	2500	2250	1550	2250	1500	1500	1700	2300	2000	2500	2000	2200
.020	2800	5500	5000	4800	4520	3400	5000	3500	2900	3700	4700	4100	4500	4000	4300
.030	4500	7500	6900	6600	6370	5500	8000	5300	4000	5700	7200	6900	5980	6200	6570
.040	6060	8040	7600	8000	7420	7900	10000	6600	5500	7500	9400	8950	7450	8150	8490
.050	7500	8100	7740	8650	8000	9500	11450	9000	6900	9210	10350	10350	8500	9500	9680
.060	8500	8150	7790	9000	8360	10700	12300	10400	8100	10380	11000	11300	9500	10350	10540
.070	8400	7920	7690	9280	8320	11650	12950	11500	9050	11290	11210	11830	10500	10800	11090
.080	8310	7710	7500	9300	8200	12360	13500	12300	10000	12040	11380	12020	11000	11210	11400
.090	8120	7580	7340	9100	8030	13000	14000	12950	10800	12690	11500	12080	11700	11440	11680
.100	7950	7410	7190	8880	7860	13500	14300	13500	11440	13190	11370	12100	12250	11440	11790
.150	7470	6950	6680	8420	7380	15200	15400	15100	13500	14800	10710	11670	12330	10590	11330
.200	7190	6630	6400	7960	7040	16370	15620	16330	14700	15760	10280	11140	11590	9620	10660
.250	6880	6420	6150	7580	6760	16650	15250	16990	15450	16090	10000	10730	10970	9240	10240
.300	6670	6250	5970	7320	6550	16550	15230	17220	15800	16200	9830	10370	10450	8800	9860
.350	6420	6120	5810	7140	6370	16330	15030	16890	15500	15940	9620	10050	9990	8410	9520
.400	6220	5980	5670	6870	6180	15780	14750	16390	15460	15600	9440	9750	9620	8070	9220
.450	6100	5850	5580	6710	6060	14740	14200	15920	15420	15070	9290	9450	9270	7800	8950
.475	6010	5780	5500	6690	5990	14040	13880	15390	15290	14650	9180	9330	9110	7720	8840
Maximum load	8500	8150	7790	9440	8470	16710	15620	17220	15800	16340	11500	12350	12560	11500	11980
Withdrawal	.060	.060	.060	.075	.064	.275	.200	.300	.300	.269	.090	.120	.135	.094	.110

PLATE XII

DIRECT PULL TESTS

Untreated White Oak Tie No. 9

Pennsylvania Cut Spike—Driven 5½ Inches, No Hole
D. L. & W. Screw Spike—Driven 6 Inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table VIII

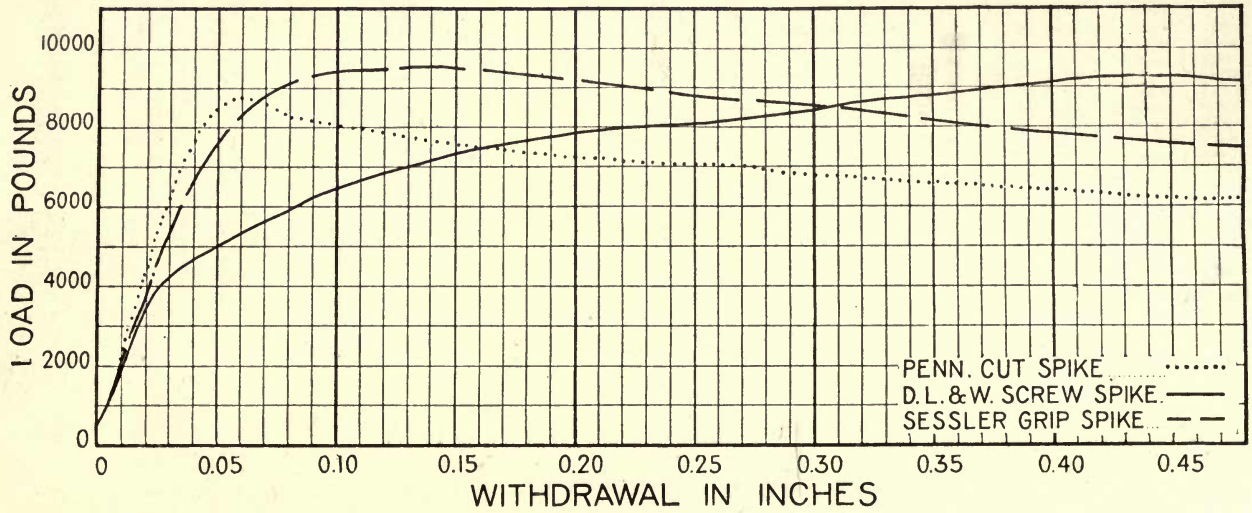


TABLE VIII

DIRECT PULL TESTS. UNTREATED WHITE OAK TIE. NO. 9

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches No Hole					D. L. & W. Screw 6 Inches Driven into ⅝-inch Hole					Sessler Grip 5½ Inches No Hole				
Laboratory Number	7704	7705	7706	7707		7708	7709	7710	7711		7712	7713	7714	7715	
Withdrawal Inches	17 P at b	18 P at d	19 P at j	20 P at i	Average	5 S at a	6 S at f	11 S at i	13 S at h	Average	1 G at c	2 G at e	3 G at g	15 G at k	Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	1080	2800	3000	2100	2250	2500	2000	980	2000	1870	2000	1000	3000	1800	1950
.020	3200	5150	5100	4400	4460	3700	3360	3000	3300	3340	4200	2000	5000	3500	3680
.030	5000	7000	6500	6500	6250	4300	4010	4650	3900	4220	6000	2800	6700	5500	5250
.040	7000	8450	7700	7600	7690	4680	4310	5500	4270	4690	7100	4100	8000	6900	6530
.050	8500	9100	8500	7980	8520	5000	4550	6000	4500	5010	8000	5200	8900	7970	7520
.060	9200	9410	8620	7850	8770	5300	4850	6400	4800	5340	8500	6450	9820	8580	8340
.070	9310	9080	8170	7660	8560	5600	5140	6710	5060	5630	8800	7300	10030	9000	8780
.080	9090	8760	7880	7400	8280	5900	5420	6960	5400	5920	9030	8000	10150	9280	9120
.090	8930	8630	7800	7150	8130	6170	5650	7190	5700	6180	9200	8530	10300	9380	9350
.100	8870	8580	7740	6880	8020	6430	5870	7480	5940	6430	9320	8940	10420	9220	9480
.150	8370	8060	7270	6530	7560	7500	6830	8220	6890	7360	9060	9680	10120	9110	9490
.200	8020	7640	7070	6240	7240	8030	7500	8700	7140	7840	8810	9430	9700	8710	9160
.250	7770	7380	6780	6130	7020	8040	7740	9200	7240	8060	8490	9160	9380	8240	8820
.300	7490	7130	6590	5850	6770	8420	7970	9450	7630	8370	8190	8810	9150	7860	8500
.350	7270	6890	6410	5640	6550	8750	8340	9730	8300	8780	7900	8370	8860	7590	8180
.400	7100	6750	6260	5460	6390	9260	8640	9920	8830	9160	7660	8030	8620	7360	7920
.450	6870	6520	6090	5300	6200	9520	8740	9960	8980	9300	7370	7630	8390	7130	7630
.475	6880	6450	6000	5260	6150	9420	8670	9730	8810	9160	7250	7440	8290	7060	7510
Maximum load	9340	9410	8650	8000	8850	9550	8740	9960	9000	9310	9380	9680	10420	9430	9730
Withdrawal	.067	.060	.061	.045	.058	.458	.450	.450	.445	.451	.118	.150	.100	.124	.123

PLATE XIII

DIRECT PULL TESTS

Untreated Douglas Fir Tie No. 10

Pennsylvania Cut Spike—Driven 5½ Inches, No Hole
D. L. & W. Screw Spike—Driven 6 Inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table IX

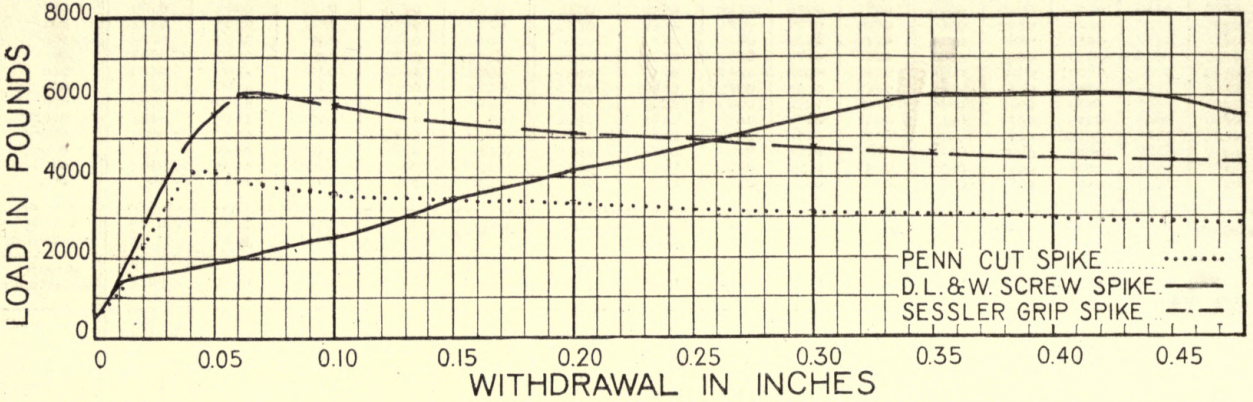


TABLE IX

DIRECT PULL TESTS. UNTREATED DOUGLAS FIR TIE. NO. 10

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches No Hole					D. L. & W. Screw 6 Inches Driven into ⅝-inch Hole					Sessler Grip 5½ Inches No Hole				
Laboratory Number	7728	7729	7730	7731		7732	7733	7734	7735		7736	7737	7738		
Withdrawal Inches	1 P at k	2 P at h	3 P at f	4 P at b	Average	1 S at j	3 S at d	4 S at a	8 S at g	Average	2 G at c	4 G at e	15 G at i		Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500		500
.010	1070	1300	750	1800	1230	1000	1630	1420	1320	1340	1800	1000	1700		1500
.020	2500	2160	1000	3550	2300	1240	1850	1790	1540	1610	3000	2500	2900		2800
.030	3700	3400	2220	4100	3360	1510	1960	1820	1610	1730	4000	4000	4000		4000
.040	3920	4500	4050	4050	4130	1600	2010	1910	1700	1810	5000	5030	4850		4960
.050	3560	4670	4540	3780	4140	1650	2130	2000	1830	1900	5560	5990	5250		5600
.060	3510	4170	4350	3690	3930	1740	2260	2120	1920	2020	6040	6600	5480		6040
.070	3480	4070	4180	3600	3830	1850	2430	2260	2040	2150	6200	6740	5370		6100
.080	3430	4000	4040	3550	3760	2000	2580	2430	2200	2300	6180	6650	5220		6020
.090	3400	3930	3980	3510	3710	2120	2750	2600	2340	2450	6100	6570	5050		5910
.100	3350	3890	3930	3480	3660	2280	2900	2700	2470	2590	6080	6460	4900		5810
.150	3210	3700	3720	3250	3470	3200	3900	3530	3240	3470	5380	6150	4620		5380
.200	3120	3560	3560	3070	3330	3800	4700	4150	3990	4160	5070	5810	4450		5110
.250	3010	3460	3450	2930	3210	4380	5360	4830	4780	4840	4890	5580	4320		4930
.300	2920	3380	3320	2780	3100	4940	6100	5370	5550	5490	4800	5370	4160		4780
.350	2900	3390	3250	2680	3060	5530	6560	5900	6050	6010	4690	5260	4040		4660
.400	2750	3250	3180	2620	2950	5790	6520	6090	5930	6080	4540	5100	3920		4520
.450	2690	3150	3160	2550	2890	5870	6200	5940	5850	5970	4450	5020	3820		4430
.475	2650	3250	3120	2510	2880	5850	4750	5830	5590	5510	4400	4980	3800		4390
Maximum load	4000	4750	4540	4240	4380	5870	6620	6180	6150	6210	6200	6740	5500		6150
Withdrawal	.037	.048	.050	.034	.042	.450	.387	.421	.372	.408	.067	.068	.063		.066

PLATE XIV

DIRECT PULL TESTS

Untreated Douglas Fir Tie No. 11

Pennsylvania Cut Spike—Driven 5½ Inches into ½-inch Hole
D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole
Sessler Grip Spike—Driven 5½ Inches into ⅞-inch Hole

To Accompany Table X

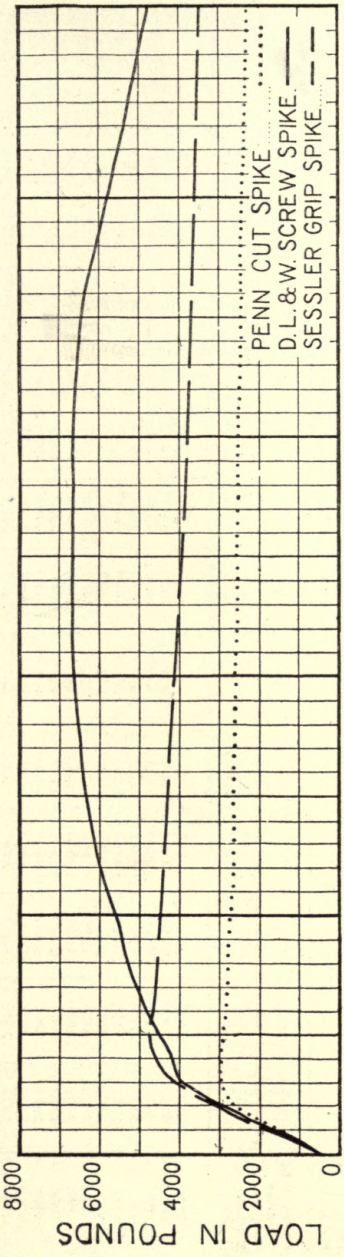


TABLE X

DIRECT PULL TESTS. UNTREATED DOUGLAS FIR TIE. NO. 11

Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches Into ½-inch Hole					D. L. & W. Screw 6 Inches Screwed into ⅝-inch Hole					Sessler Grip 5½ Inches Into $\frac{7}{16}$-inch Hole				
Laboratory Number	7739	7740	7741	7742		7743	7744	7745	7746		7747	7748	7750	7751	
Withdrawal Inches	5 P at i	6 P at i	7 P at f	8 P at a	Average	11 S at j	12 S at g	13 S at c	14 S at d	Average	1 G at k	2 G at h	3 G at e	6 G at b	Average
.000	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
.010	1800	1500	1600	1800	1680	1600	1970	1500	1700	1690	2450	1800	1700	1500	1860
.020	2500	2670	2800	3000	2740	3000	3000	2600	3000	2900	3600	3000	3000	2650	3060
.030	2420	3290	2840	3150	2930	4000	3670	3380	3800	3710	4520	4090	3600	3880	4020
.040	2530	3350	2660	3190	2940	4550	4100	3830	4200	4170	5160	4750	4200	4340	4610
.050	2570	3190	2590	3240	2900	4900	4500	4200	4520	4530	5080	5000	4550	4480	4780
.060	2500	3190	2580	3290	2890	5180	4800	4520	4780	4820	4980	4970	4560	4350	4720
.070	2400	3190	2570	3310	2870	5400	5000	4750	5000	5040	4860	4920	4510	4240	4630
.080	2380	3160	2570	3260	2840	5600	5200	4960	5240	5250	4800	4830	4450	4180	4570
.090	2350	3080	2560	3160	2790	5820	5370	5200	5400	5450	4770	4800	4400	4170	4540
.100	2330	3050	2550	3080	2750	6020	5500	5420	5570	5630	4690	4710	4300	4150	4460
.150	2260	2920	2530	2940	2660	6810	6000	6090	6400	6330	4420	4460	4060	4040	4250
.200	2290	2820	2490	2840	2610	7060	6280	6330	6830	6630	4260	4250	3980	3990	4120
.250	2250	2760	2430	2790	2560	7290	6180	6290	7130	6720	4120	4070	3720	3860	3940
.300	2210	2690	2380	2710	2500	7190	6050	6530	7120	6720	3960	4000	3610	3760	3830
.350	2180	2610	2360	2670	2460	6940	5860	6230	6860	6470	3840	3850	3530	3700	3730
.400	2160	2590	2310	2640	2430	6380	5400	5730	6030	5890	3710	3750	3450	3650	3640
.450	2150	2530	2270	2580	2380	5680	4780	5110	4860	5110	3640	3650	3300	3550	3540
.475	2140	2450	2240	2550	2350	5350	4670	4920	4450	4850	3590	3750	3280	3510	3530
Maximum load	2570	3400	3000	3320	3070	7350	6280	6530	7200	6890	5170	5000	4580	4480	4810
Withdrawal	.049	.038	.021	.075	.046	.275	.200	.300	.275	.263	.037	.048	.061	.050	.049

directly as an observation; in such cases the loads were interpolated from the original curves plotted for each individual spike. Owing to the numerous points obtained this interpolation introduced no appreciable inaccuracy.

Plates VII to XIV show graphically the average resistance developed by the four spikes of each type in the same tie for given amounts of withdrawal.

REDRIVE AND PULLING TESTS

In accordance with the suggestion made by the engineers of several of the Eastern Railroads, redrive and pulling tests were made to determine the effect of the successive redriving of a spike after having been withdrawn 0.25 of an inch. It is believed that such tests will give some information as to the influence upon the holding power of the spike when redriven after having been lifted in service. Six such tests were made for each type of spike in each of the four kinds of ties.

Each spike was withdrawn ¼ of an inch, redriven or rescrewed, withdrawn again for ¼ of an inch, again redriven and withdrawn, making three withdrawals in all. In these tests the same spikes and the same sizes of preformed holes were used as in the direct pulling tests.

Eighteen spikes were tested in each tie, as follows:

(*a*) 3 Pennsylvania cut spikes driven 5½ inches without bored hole;
(*b*) 3 Pennsylvania cut spikes driven 5½ inches into ½-inch hole;
(*c*) 3 D. L. & W. screw spikes screwed 6 inches into 5-8-inch hole;
(*d*) 3 D. L. & W. screw spikes driven into 5-8-inch hole to within 2 inches of the head and screwed to within ½-inch of the head;
(*e*) 3 Sessler Grip spikes driven 5½ inches without bored hole;
(*f*) 3 Sessler Grip spikes driven 5½ inches into 7-16-inch bored hole.

METHOD OF TEST

The method of testing was similar to that already described under the direct pulling tests, except that the spikes were withdrawn only ¼ of an inch. The cut spike and the Sessler Grip spike were then redriven, and the screw spike rescrewed, the full amount of the withdrawal in all cases. The spikes were then repulled ¼ of an inch, redriven or rescrewed, respectively, and again repulled.

Results of Redrive and Pulling Tests

PLATE XV

REPULLING TESTS

Untreated Chestnut Tie No. 3

..... Pennsylvania Cut Spike—Driven 5½ Inches, No Hole

———— D. L. & W. Screw Spike—Driven 4½ Inches and Screwed 1½ Inches into ⅝-inch Hole

— — — — Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table XI

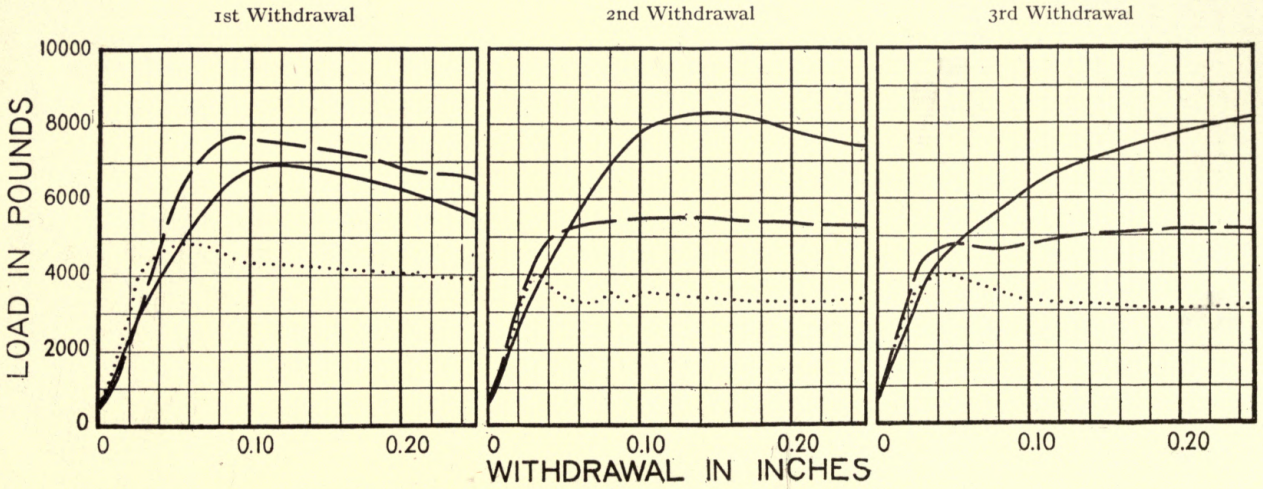


TABLE XI

REPULLING TESTS. UNTREATED CHESTNUT TIE. NO. 3

Average Resistance in Pounds

Type of Spike:	Pennsylvania Cut			D. L. & W. Screw			Sessler Grip		
Depth of Penetra'n:	5½ Inches			6 Inches			5½ Inches		
Method of Driving:	No Hole			Driven 4½ Inches and Screwed 1½ Inches in ⅝-inch Hole			No Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1710	1670	1950	1450	1590	1440	1080	1700	1830
.020	3100	3020	2930	2540	2530	2380	2300	3170	3200
.030	4210	3690	3940	3580	3430	3230	3530	4270	4320
.040	4670	3960	3700	4280	4280	3990	4830	4910	4710
.050	4770	3870	3420	4730	5010	4610	5970	5120	4810
.060	4840	3760	3330	5190	5770	5220	6740	5240	4760
.070	4760	3650	3280	5460	6340	5770	7240	5330	4710
.080	4600	3580	3590	5740	6970	6230	7510	5400	4720
.090	4480	3200	3240	5980	7420	6610	7680	5450	4770
.100	4400	3500	3230	6210	7780	6800	7660	5460	4850
.125	4290	3420	3190	—	—	—	7450	5570	4990
.150	4190	3360	3120	7130	8250	6790	7270	5530	5060
.175	4100	3300	3090	—	—	—	7090	5460	5170
.200	4010	3240	3060	7700	7800	6210	6840	5370	5210
.225	3960	3270	3090	—	—	—	6700	5360	5310
.250	3920	3340	3130	8150	7360	5530	6530	5350	5190
Average maximum load	5310	4180	4090	8220	8310	7020	7780	5640	5350
Withdraw at average maximum load	.046	.035	.034	.239	.143	.135	.097	.142	.242

PLATE XVI

REPULLING TESTS

Untreated Chestnut Tie No. 3

..... Pennsylvania Cut Spike—Driven 5¼ Inches into ½-inch Hole

———— D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole

— — — — Sessler Grip Spike—Driven 5½ Inches into ⅞-inch Hole

To Accompany Table XII

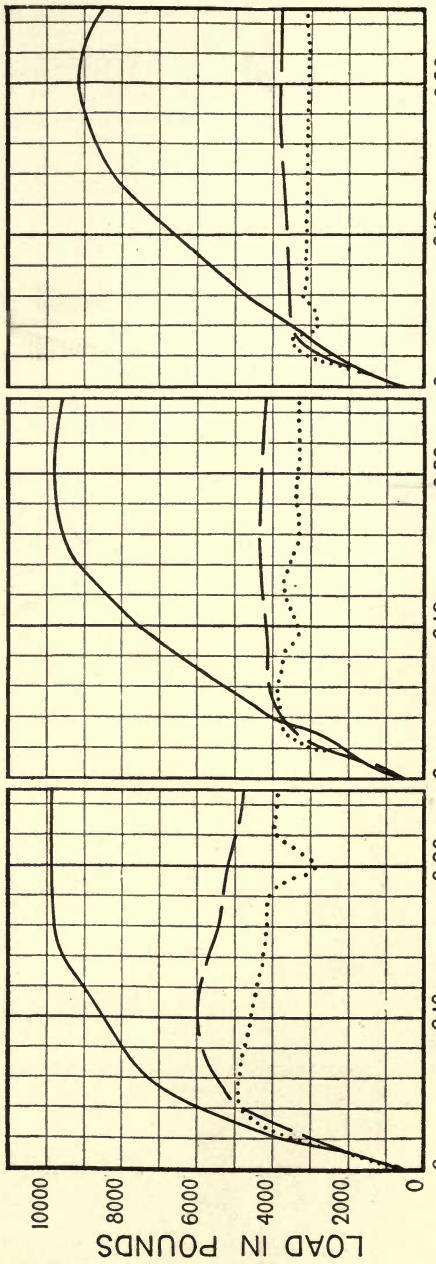


TABLE XII

REPULLING TESTS. UNTREATED CHESTNUT TIE. NO. 3

Average Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches Into ½-inch Hole			D. L. & W. Screw 6 Inches Screwed into 5/16-inch Hole			Sessler Grip 5½ Inches Into ⅜-inch Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1880	1390	1750	1830	1400	1450	1770	1630	1730
.020	3370	2910	3000	3730	2020	2280	3000	2800	2760
.030	4340	3640	3480	4770	2730	2960	3900	3390	3340
.040	4820	3360	2850	5800	3930	3580	4870	3750	3560
.050	4930	3780	2890	6660	4520	4150	5200	3940	3520
.060	4900	3810	3230	7250	5140	4700	5440	4030	3550
.070	4830	3740	3180	7650	5770	5130	5730	4060	3600
.080	4740	3710	3150	7990	6430	5610	5870	4090	3620
.090	4640	3370	3110	8240	6990	6060	5940	4130	3640
.100	4620	3360	3110	8480	7520	6530	5990	4170	3690
.125	4390	3700	3110	—	—	—	5860	4230	3760
.150	4240	3360	3080	9760	9530	8490	5540	4330	3880
.175	4120	3310	3060	—	—	—	5310	4340	3850
.200	2870	3300	3050	9850	9770	9200	5120	4270	3790
.225	3930	3290	3060	—	—	—	4940	4180	3790
.250	3840	3300	3070	9860	9640	8580	4800	4160	3790
Average maximum load	5210	3930	3740	10020	9930	9260	6240	4360	3880
Withdrawal at average maximum load	.049	.037	.028	.221	.189	.196	.088	.164	.174

PLATE XVII

REPULLING TESTS

Treated Yellow Pine Tie No. 6

..... Pennsylvania Cut Spike—Driven 5½ Inches, No Hole
———— D. L. & W. Screw Spike—Driven 4½ Inches and Screwed 1½ Inches into ⅝-inch Hole
— — — — Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table XIII

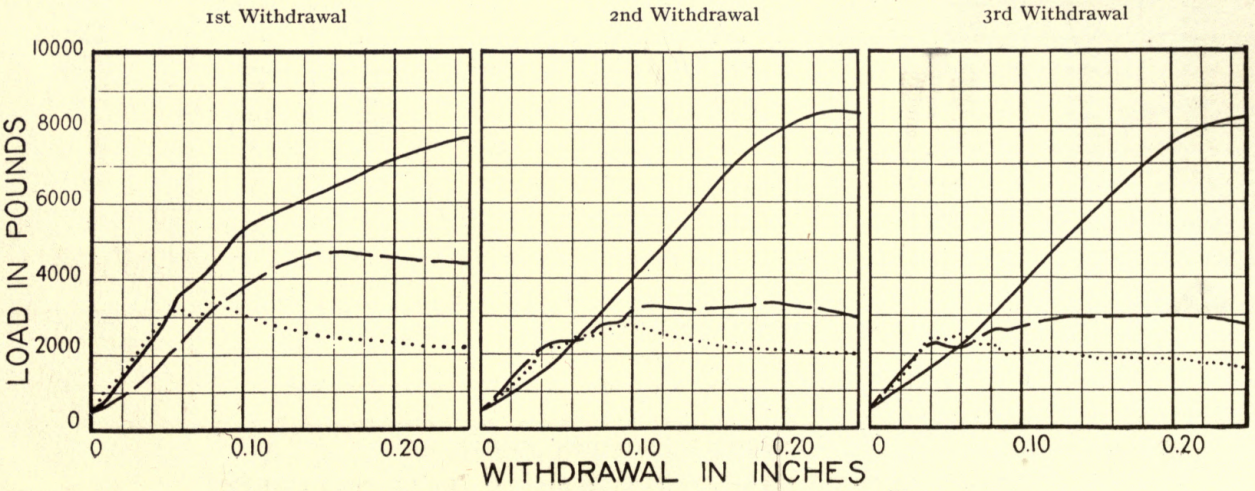


TABLE XIII

REPULLING TESTS. TREATED YELLOW PINE. NO. 6

Average Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches No Hole			D. L. & W. Screw 6 Inches Driven 4½ Inches and Screwed 1½ Inches into ⅝-Inch Hole			Sessler Grip 5½ Inches No Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1030	810	990	980	710	760	740	870	1010
.020	1490	1200	1460	1510	950	1050	950	1290	1500
.030	2030	1650	1990	1980	1230	1330	1270	1780	1930
.040	2690	2220	2440	2510	1570	1630	1610	2210	2230
.050	3090	2180	2330	2950	1930	1930	2050	2290	2220
.050	3120	2400	2540	3780	2330	2300	2410	2290	2180
.070	2910	2580	2270	3950	2770	2680	2810	2480	2450
.080	3570	2670	2230	4360	3150	3040	3220	2860	2750
.090	3190	2860	1970	4760	3620	3430	3700	2810	2660
.100	3030	2860	2020	5300	4070	3860	3840	3150	2700
.150	2590	2230	1840	6180	6350	5830	4030	3140	2930
.200	2330	2050	1850	7180	7980	7500	3870	3280	3000
.250	2180	1950	1650	7800	8430	8240	3610	2960	2730
Average maximum load	4120	3510	3080	7800	8500	8650	4700	3750	3360
Withdrawal at average maximum load	.092	.070	.055	.250	.246	.247	.140	.138	.128

PLATE XVIII

REPULLING TESTS

Treated Yellow Pine Tie No. 6

..... Pennsylvania Cut Spike—Driven 5½ Inches into ½-inch Hole

———— D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole

— — — — Sessler Grip Spike—Driven 5½ Inches into ½-inch Hole

To Accompany Table XIV

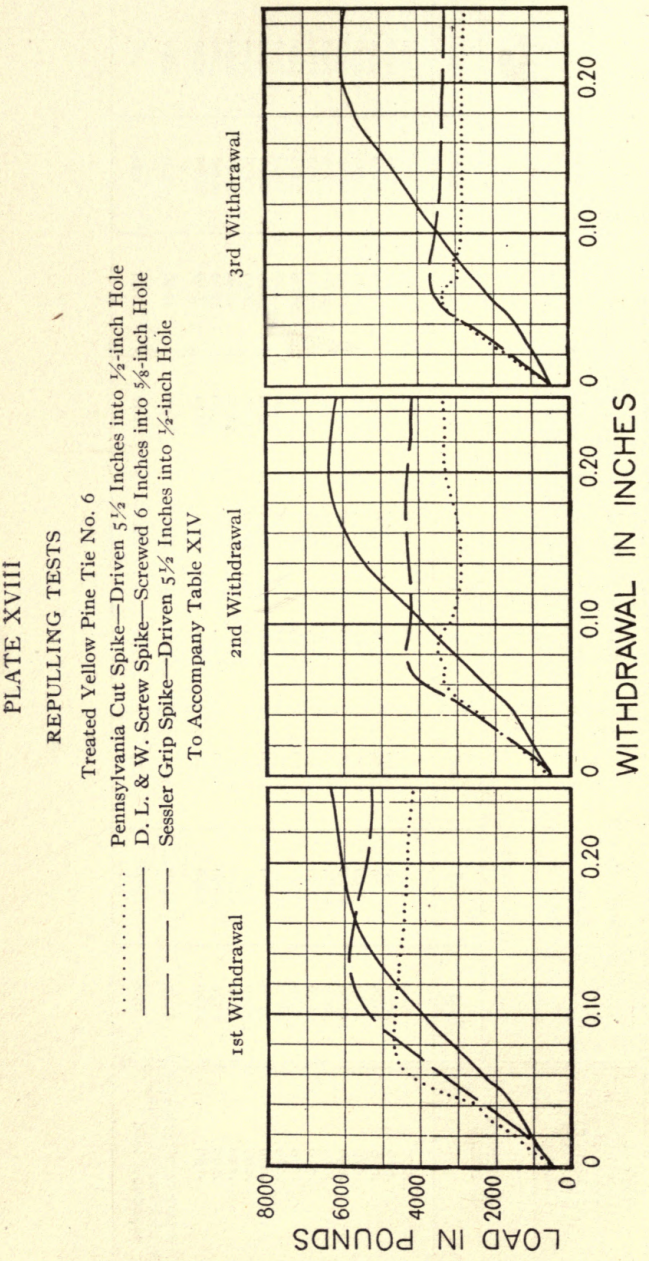


TABLE XIV

REPULLING TESTS. TREATED YELLOW PINE. NO. 6

Average Resistance in Pounds

Type of Spike:	Pennsylvania Cut			D. L. & W. Screw			Sessler Grip		
Depth of Penetra'n:	5½ Inches			6 Inches			5½ Inches		
Method of Driving:	Into ½-inch Hole			Screwed into 5/16-inch Hole			Into 7/16-inch Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1070	820	1120	840	770	750	880	960	1000
.020	1590	1470	1640	1060	980	950	1340	1460	1550
.030	2170	2000	2240	1300	1270	1230	1780	1930	2110
.040	2550	2450	2780	1610	1630	1540	2260	2530	2730
.050	3620	2960	3330	1950	1890	1840	2850	3000	3270
.060	4300	3300	3300	2350	2300	2220	3430	3880	3610
.070	4650	3290	2940	2700	2710	2550	3990	4140	3700
.080	4750	3550	3040	3180	3130	2920	4470	4340	3670
.090	4770	3460	2870	3580	3500	3280	4930	4190	3620
.100	4760	3130	2880	3990	3880	3590	5380	4160	3540
.150	4480	2860	2810	5540	5780	4900	5800	4250	3420
.200	4300	3220	2880	6090	6420	5990	5460	4320	3320
.250	4120	2210	2730	6290	6230	5940	5210	4140	3230
Average maximum load	4980	3600	3680	6340	6460	6440	5910	4680	3800
Withdrawal at average maximum load	.082	.066	.050	.230	.206	.232	.128	.119	.079

PLATE XIX

REPULLING TESTS

Untreated White Oak Tie No. 12

..... Pennsylvania Cut Spike—Driven 5½ Inches, No Hole

——— D. L. & W. Screw Spike—Driven 4½ Inches and Screwed 1½ Inches into ⅝-inch Hole

— — — Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table XV

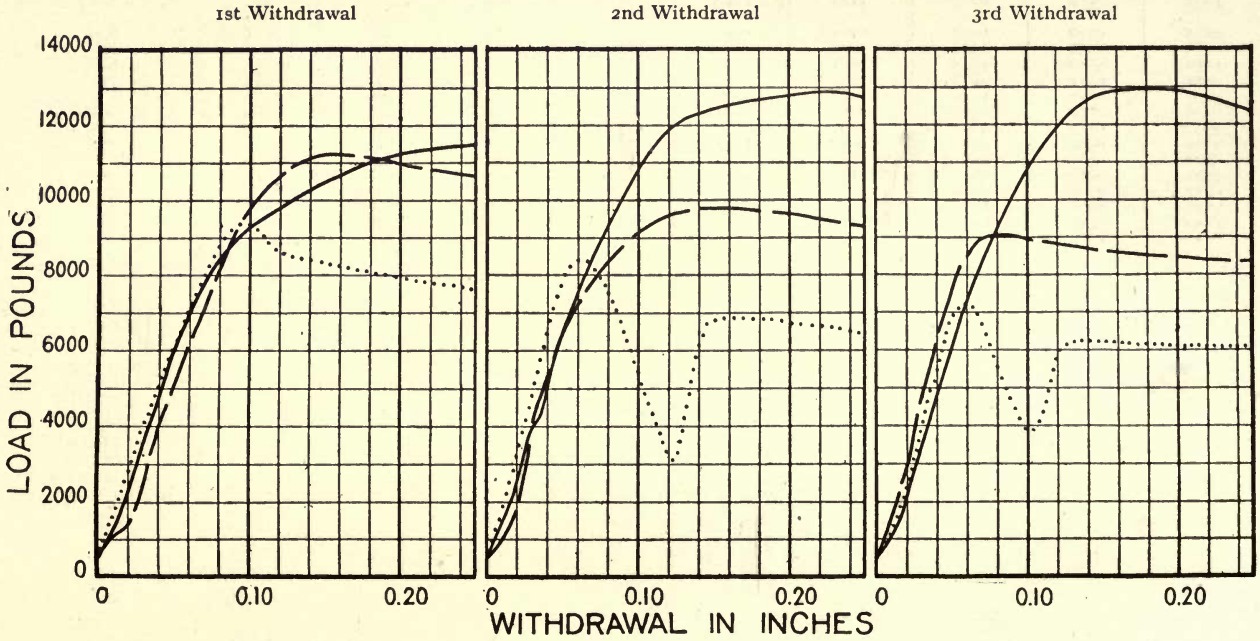


TABLE XV

REPULLING TESTS. UNTREATED WHITE OAK. NO. 12

Average Resistance in Pounds

Type of Spike:	Pennsylvania Cut			D. L. & W. Screw			Sessler Grip		
Depth of Penetra'n:	5½ Inches			6 Inches			5½ Inches		
Method of Driving:	No Hole			Driven 4½ Inches and Screwed 1½ Inches into ⅝-inch Hole			No Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1600	1690	1230	1250	1110	1160	1090	1460	1630
.020	2830	3130	2500	2430	1970	2130	1430	2610	3030
.030	4050	4860	4000	3720	4030	3430	2680	3970	4800
.040	5140	6630	5570	4830	5330	4730	3870	4630	6370
.050	6280	7950	6940	6170	5420	6120	4790	6320	7670
.060	7190	8400	7250	7110	7490	7350	6060	7140	8500
.070	8050	8180	6520	7910	8450	8260	7220	7880	8940
.080	8870	7520	5490	8510	9220	9250	8250	8410	9060
.090	9350	6550	4550	8940	10040	10100	9160	8840	9010
.100	9370	5320	3850	9290	10840	10840	9780	9170	8940
.125	8560	3090	6170	—	—	—	10850	9680	8820
.150	8310	6800	6270	10440	12460	12840	11150	9750	8670
.175	8090	6820	6180	—	—	—	11170	9690	8540
.200	7930	6730	6130	11310	12800	12850	10950	9560	8450
.225	7790	6640	6090	—	—	—	10800	9480	8390
.250	7650	6460	6080	11510	12730	12380	10600	9360	8330
Average maximum load	9720	8580	7590	11620	12960	12930	11390	9940	9080
Withdrawal at average maximum load	.099	.070	.060	.233	.233	.175	.147	.131	.493

PLATE XX

REPULLING TESTS

Untreated White Oak Tie No. 12

..... Pennsylvania Cut Spike—Driven 5½ Inches into ½-inch Hole

——— D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole

— — — Sessler Grip Spike—Driven 5½ Inches into ⅞-inch Hole

To Accompany Table XVI

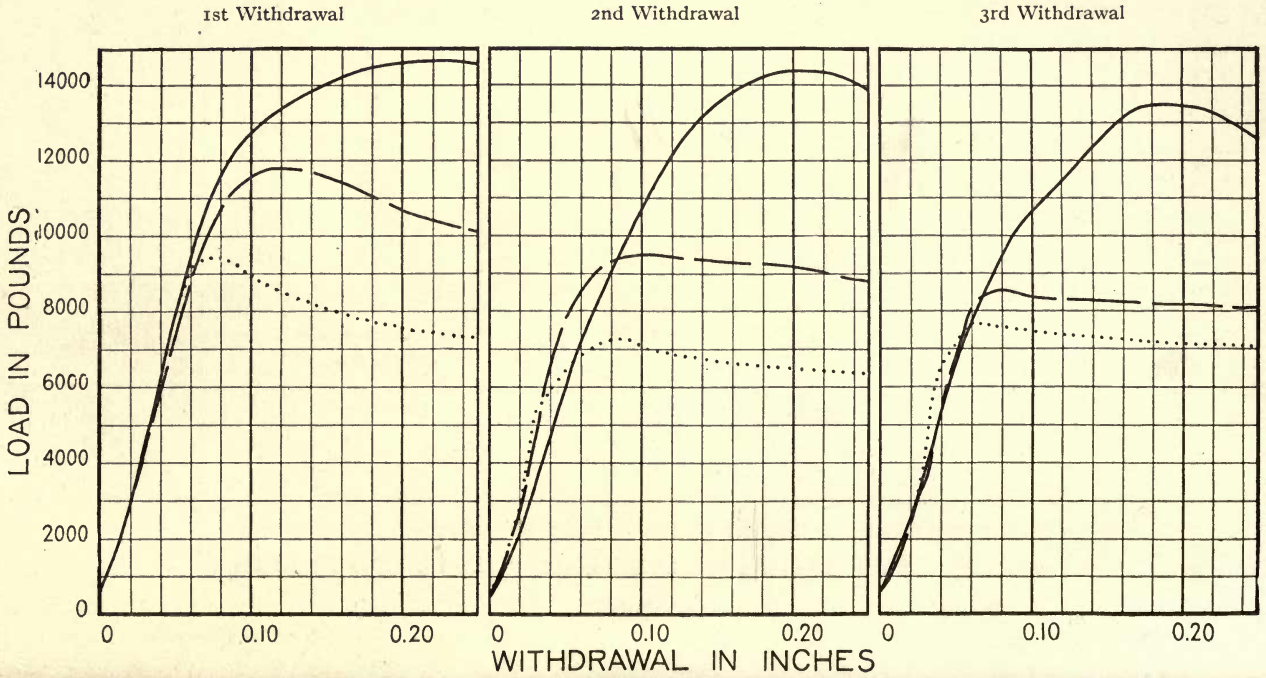


TABLE XVI

REPULLING TESTS. UNTREATED WHITE OAK. NO. 12

Average Resistance in Pounds

Type of Spike: Depth of Penetra'n: Method of Driving:	Pennsylvania Cut 5½ Inches Into ½-inch Hole			D. L. & W. Screw 6 Inches Screwed into ⅝-inch Hole			Sessler Grip 5½ Inches Into 7/16-inch Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1580	1450	1420	1670	1180	1170	1630	1450	1380
.020	2700	2800	2680	2900	2340	2450	2930	2830	2520
.030	4670	5330	4430	4530	3700	3970	4330	4780	3780
.040	6380	5850	6430	6280	5000	5410	5780	6380	5480
.050	7820	6500	7030	7900	6110	6600	7470	7830	7030
.060	9070	6830	6 60	9520	7220	7640	8870	8620	8010
.070	9330	7070	6670	10730	8230	8540	9990	9010	8500
.080	9380	7260	6590	11600	9070	9280	10760	9280	8510
.090	9190	7200	6510	12250	9950	10010	11230	9420	8450
.100	8910	7000	6440	12690	10690	10620	11590	9530	8380
.125	8430	6880	6330	—	—	—	11850	9510	8280
.150	8050	6730	6220	14010	13520	12870	11510	9370	8250
.175	7770	6650	6170	—	—	—	11110	9250	8170
.200	7600	6560	6130	14680	14300	13400	10700	9140	8100
.225	7400	6450	6070	—	—	—	10380	8990	8080
.250	7270	6370	6020	14490	13850	12650	10110	8810	8030
Average maximum load	9400	7710	7150	14740	14530	13400	11940	9590	8690
Withdrawal at average maximum load	.080	.062	.061	.207	.208	.200	.121	.107	.074

PLATE XXI

REPULLING TESTS

Untreated Douglas Fir Tie No. 13

..... Pennsylvania Cut Spike—Driven 5½ Inches, No Hole

———— D. L. & W. Screw Spike—Driven 4½ Inches and Screwed 1½ Inches into ⅝-inch Hole

— — — Sessler Grip Spike—Driven 5½ Inches, No Hole

To Accompany Table XVII

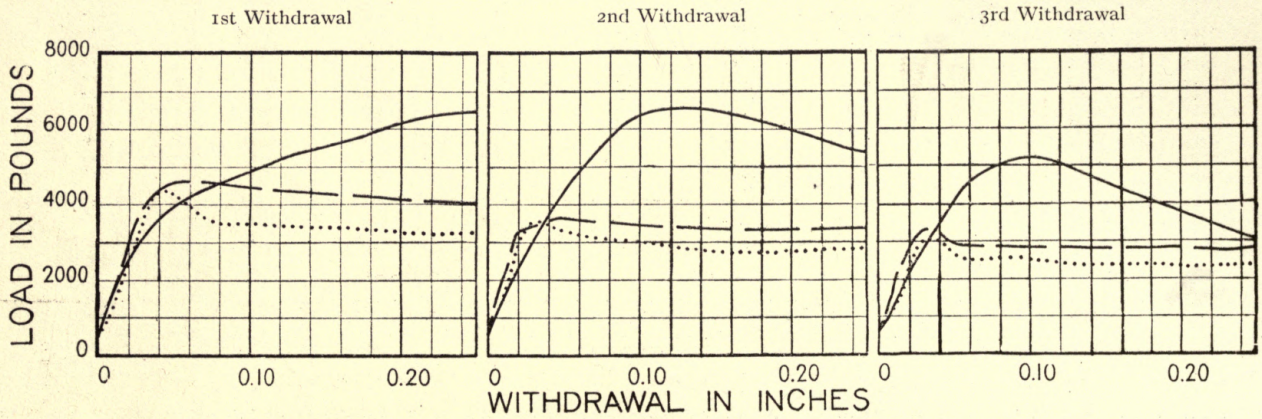


TABLE XVII

REPULLING TESTS. UNTREATED DOUGLAS FIR. NO. 13

Average Resistance in Pounds

Type of Spike:	Pennsylvania Cut			D. L. & W. Screw			Sessler Grip		
Depth of Penetra'n:	5¼ Inches			6 Inches			5¼ Inches		
Method of Driving:	No Hole			Driven 4½ Inches and Screwed 1½ Inches into ⅝-inch Hole			No Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1330	1500	1340	1560	1450	1240	1800	1870	1920
.020	2580	2080	2530	2550	2330	2200	2950	3250	2860
.030	3820	3630	3000	3170	3080	2900	3940	3390	3360
.040	4300	3380	2980	3670	3710	3540	4320	3630	3170
.050	4140	3160	2650	3950	4310	4100	4530	3660	2930
.060	3910	3140	2550	4170	4870	4520	4640	3660	2900
.070	3640	3000	2500	4400	5330	4830	4650	3590	2860
.080	3570	3040	2560	4560	5800	5010	4600	3520	2820
.090	3530	3030	2520	4720	6080	5120	4530	3500	2820
.100	3530	2990	2520	4840	6320	5200	4470	3460	2810
.125	3450	2890	2390	5260	6550	4980	4320	3450	2810
.150	3350	2870	2360	5560	6450	4500	4250	3410	2810
.175	3300	2840	2340	5860	6230	4160	4170	3350	2830
.200	3240	2820	2270	6110	5940	3780	4090	3340	2810
.225	3220	2840	2290	6290	5670	3430	4050	3330	2780
.250	3180	2810	2290	6390	5300	3090	4000	3350	2880
Average maximum load	4530	3500	3350	6440	6600	5260	4680	3710	3370
Withdrawal at average maximum load	.042	.033	.027	.245	.129	.109	.062	.049	.030

PLATE XXII

REPULLING TESTS

Untreated Douglas Fir Tie No. 13

..... Pennsylvania Cut Spike—Driven 5½ Inches into ½-inch Hole

———— D. L. & W. Screw Spike—Screwed 6 Inches into ⅝-inch Hole

— — — Sessler Grip Spike—Driven 5½ Inches into ¼-inch Hole

To Accompany Table XVIII

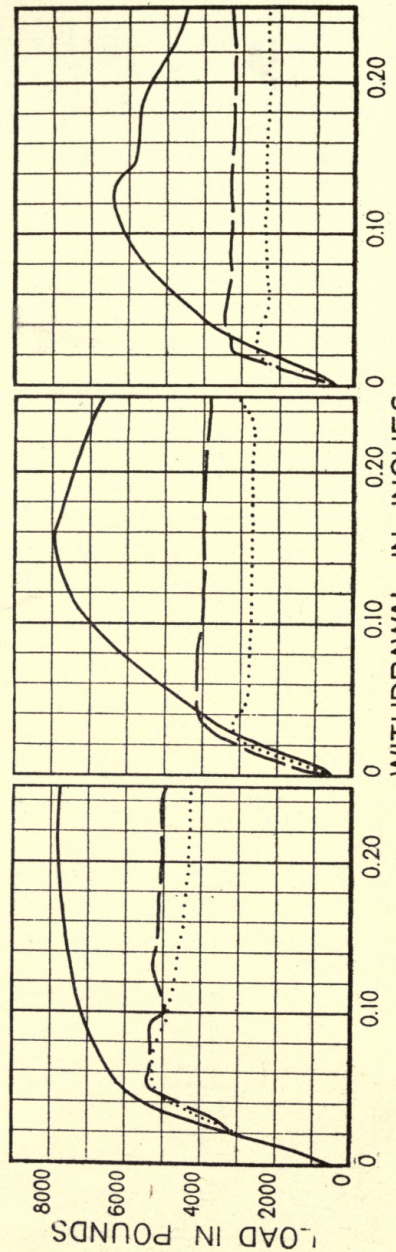


TABLE XVIII

REPULLING TESTS. UNTREATED DOUGLAS FIR. NO. 13

Average Resistance in Pounds

Type of Spike:	Pennsylvania Cut			D. L. & W. Screw			Sessler Grip		
Depth of Penetra'n:	5⅛ Inches			6 Inches			5½ Inches		
Method of Driving:	Into ½-inch Hole			Screwed into ⅝-inch Hole			Into ⅞-inch Hole		
Withdrawal in Inches	Withdrawals			Withdrawals			Withdrawals		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
.000	500	500	500	500	500	500	500	500	500
.010	1600	1550	1700	1860	1430	1430	1770	2040	1800
.020	3020	2830	2640	3350	2460	2420	2930	3110	3070
.030	3650	3210	2670	4710	3390	3330	3940	3890	3230
.040	3540	3000	2480	5570	4090	3890	4760	4080	3490
.050	3340	2830	2270	6070	4680	4380	5200	4140	3410
.060	3330	2800	2280	6420	5190	4820	5220	4130	3350
.070	3320	2800	2290	6680	5710	5250	5200	4120	3310
.080	3300	2790	2310	6870	6220	5660	5100	4100	3280
.090	3350	2780	2320	7030	6680	5930	4980	4050	3270
.100	2920	2780	2340	7150	7070	6170	4860	4020	3260
.125	3200	2760	2320	7440	7690	6430	4680	3970	3240
.150	3130	2760	2320	7620	8000	5830	4590	3980	3210
.175	3110	2710	2290	7760	7750	5770	4450	3940	3190
.200	3050	2690	2320	7810	7410	5390	4350	3920	3180
.225	3010	2680	2340	7820	7040	4870	4270	3890	3170
.250	2990	3060	2320	7800	6590	4490	4250	3910	3230
Average maximum load	3690	3290	2480	7910	8020	6540	5370	4260	3630
Withdrawal at average maximum load	.033	.029	.090	.215	.155	.139	.065	.152	.033

RESULTS OF THE REDRIVING AND REPULLING TESTS

The results obtained from these redriving and repulling tests upon each of the three spikes of one type driven under the same conditions into each kind of tie, were averaged and the results plotted. Tables XI to XVIII are the detailed log sheets of the tests prepared in exactly the same way as the detailed log sheets for the direct pulling tests, except that only the average of three tests are given omitting the individual tests. Average curves were computed and plotted, as shown in Plates XV to XXII.

SUMMARY AND CONCLUSIONS

DIRECT PULL TESTS

The average ultimate resistance, the results of seven individual tests of the various types of spikes, driven into two or more ties of each kind under the different conditions enumerated below is as follows:

Standard Cut Spike—Pennsylvania R. R. Lines West

Kind of Tie	Without Hole	Into ½-inch Hole
Chestnut	5150	4908
Creosoted Yellow Pine	4850	4700
White Oak	9020	8790
Douglas Fir	4280	3539

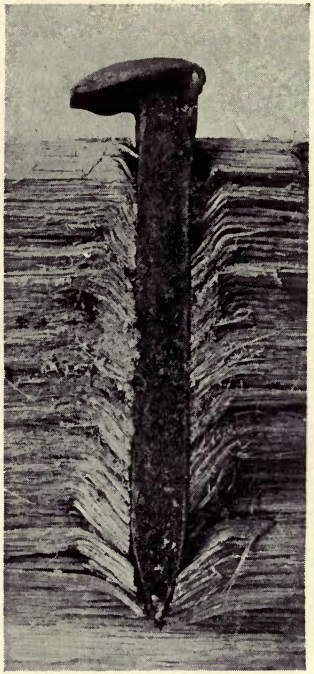
Standard Screw Spike, Delaware, Lackawanna and Western R. R.

Kind of Tie	Screwed Full Depth	Driven 4½ Inches Screwed 1½ Inches	Driven Full Depth
Chestnut	9100	6950	6200
Creosoted Yellow Pine	8500	6950	6150
White Oak	15560	11500	9200
Douglas Fir	7170	6500	6100

Sessler Grip Spike

Kind of Tie	Without Hole	Into $\frac{7}{16}$-inch Hole
Chestnut	7180	6100
Creosoted Yellow Pine	6890	6500
White Oak	10300	11800
Douglas Fir	5200	4600

PLATE XXIII



Standard Cut Spike
Pennsylvania R.R. Lines West
Driven without hole

Standard Screw Spike
Delaware, Lackawanna and Western R.R.
Driven into 5-8-inch hole

Sessler Grip Spike
American Spike Company
Driven without hole

PLATE XXIV

Standard Cut Spike
Pennsylvania R.R. Lines West
Driven into ½-inch hole

Standard Screw Spike
Delaware, Lackawanna and Western R.R.
Screwed into 5-8-inch hole

Sessler Grip Spike
American Spike Company
Driven into 7-16-inch hole

The relative ultimate holding powers of the three types of spikes tested expressed in terms of the cut spike driven without a hole for the various ties is as follows:

Relative Ultimate Holding Power

Tie	Method of Driving	Cut	Screw *	Sessler Grip
Chestnut	Without hole	100%		139.5%
	With hole	95.2%	176.6%	118.5%
Creosoted Yellow Pine	Without hole	100%		142.1%
	With hole	96.9%	175.2%	134.1%
White Oak	Without hole	100%		114.3%
	With hole	97.6%	172.7%	130.8%
Douglas Fir	Without hole	100%		121.4%
	With hole	82.7%	167.4%	107.5%
Average, all woods	Without hole	100%		129.3%
	With hole	93.1%	172.9%	122.7%

These results appear to indicate that both the cut and the Sessler Grip spike develop a slightly higher initial resistance to withdrawal when driven without a prebored hole than when driven into ½-inch and $^{7}/_{16}$-inch holes, respectively. This increase in initial holding power secured when a spike of this type is driven without preforming the hole is of doubtful value; for the efficiency and ultimate life of a spike in a tie depends not so much upon the ultimate initial resistance to withdrawal as it does upon the range of elastic behavior of the wood fibres, provided the friction between the wood fibres and the surface of the spike is sufficient.

A cut spike driven into a tie without first preforming the hole crushes and bunches the fibres over a wide area due largely to the splitting and wedging action being confined to one plane, see Plate XXIII. With the Sessler Grip spike, this splitting action appears to be less, due, partly to the shape of the point tending to produce a combined cutting and splitting action, but much more to the rotation of the spike on driving, averaging sixty-three degrees when driven without a hole and sixty-eight degrees when driven into a hole. Due to this rotation of the spike the splitting and wedging is not confined to any one plane and the accumulative effect upon the wood fibres appears to be thereby reduced.

The effect upon the wood fibres of driving instead of screwing a screw spike is obvious.

*Note. Screw spike screwed full depth.

The crushing and bunching of the wood fibres can be materially reduced both with the cut spike and the Sessler Grip spike by preforming the hole, as is illustrated in Plate XXIV.

In a spike fastening every effort should be made to preserve as far as possible the elasticity of the wood fibres. Plate XXIII and XXIV clearly show the effects upon the wood fibres of driving the three types of spikes under different conditions.

ELASTICITY OF A SPIKE FASTENING

When a spike is driven into a tie the fibres of the wood are forced downward and pressed simultaneously outward. When such a spike fastening is subjected to a direct pull, within its elastic range, the friction between the wood fibres and the surface of the spike tends to hold it in place and whatever yielding does take place is due solely to the elastic distortion of the wood fibres. When the load is released the elasticity of the wood fibres causes the spike to regain its original position. The elastic withdrawal limit of a spike fastening is reached either when the wood fibres in contact with the surface of the spike are strained beyond their elastic limit, or the bond or adhesion between the fibres of wood and the surface of the spike is insufficient to prevent relative motion between the two. Both in the cut and Sessler Grip spike failures appear to take place simultaneously in the two ways just described. In the screw spike, on the other hand, failure is more gradual, but incipient failure takes place at very low loads, probably due to the crushing of the fibres against the thread of the screw. At the same time, the frictional resistance between the shank of the spike and the wood fibres increases somewhat due to their displacement and the resultant failure is a very gradual one.

Within the elastic withdrawal limit the resistance to direct pull developed by a spike is directly proportional to the displacement of the spike in the wood. Also within the elastic withdrawal range the permanent set is practically negligible.

When the load upon a spike exceeds its elastic withdrawal limit, sliding friction comes more and more into play and the permanent sets become appreciable. The ultimate resistance to withdrawal that is actually developed by a spike depends somewhat upon the elastic strength of the wood fibres, but much more upon the friction of the bunched and distorted fibres upon each other and the surface

of the spike; the amount of this friction varies within very wide limits even in the same tie. Especially in the cut spike, this friction varies suddenly and irregularly with the amount of withdrawal, giving the load strain curve a saw tooth appearance.

To be a permanent rail fastening, a spike must not be loaded in excess of its elastic withdrawal resistance, irrespective of its ultimate resistance. A rail fastening should therefore be designed with a sufficient number of spikes so that the load per spike does not exceed the elastic withdrawal resistance of any spike. It is obvious that the least number of spikes and greatest efficiency per rail fastening will be obtained with that type of spike having the highest elastic withdrawal resistance. A proper safety factor should also be introduced in the design to allow for any possible lowering of the elastic withdrawal resistance resulting from the fatigue and physical deterioration of the wood fibres with time.

The true elastic withdrawal limits can be only approximately determined from the load stress curves, Plates VII to XIV, inclusive, as the inaccuracies of measurements introduced by the compression of the tie on the bearing blocks and the twisting, especially of a more or less warped tie, have in some cases modified the curves. This is especially true in the case of the screw spike which requires the most sensitive instruments to locate the point of incipient failure. For these reasons only general conclusions can be drawn from these tests as to the actual and relative elastic withdrawal resistances of the three types of spikes under the various conditions tested.

To determine the true elastic behavior of the three types of spikes a limited number of tests were made in which the withdrawal of the spike was measured directly to the nearest 1-10,000 part of an inch. In this investigation a creosoted yellow pine tie was used and two spikes of each type were tested using prebored holes.

The results of these tests are given in Table XIX and shown diagrammatically on Plate XXV.

Based upon the results of these tests the relative average elastic limits, taking the cut spike at 100%, is:

Cut spike	100%
Screw spike	90% elastic limit in bearing
	178% final yield point
Sessler Grip Spike	129%

PLATE XXV

Diagram Showing Relation Between Applied Load and Corresponding Withdrawal and Set

Creosoted Yellow Pine Tie

1 and 2—Cut Spike—Driven 5½ Inches into ½-inch Hole
3 and 4—Screw Spike—Screwed 6 Inches into ⅝-inch Hole
5 and 6—Sessler Grip Spike—Driven 5½ Inches into ¼-inch Hole

——— Strain Curve ..... Set Curve

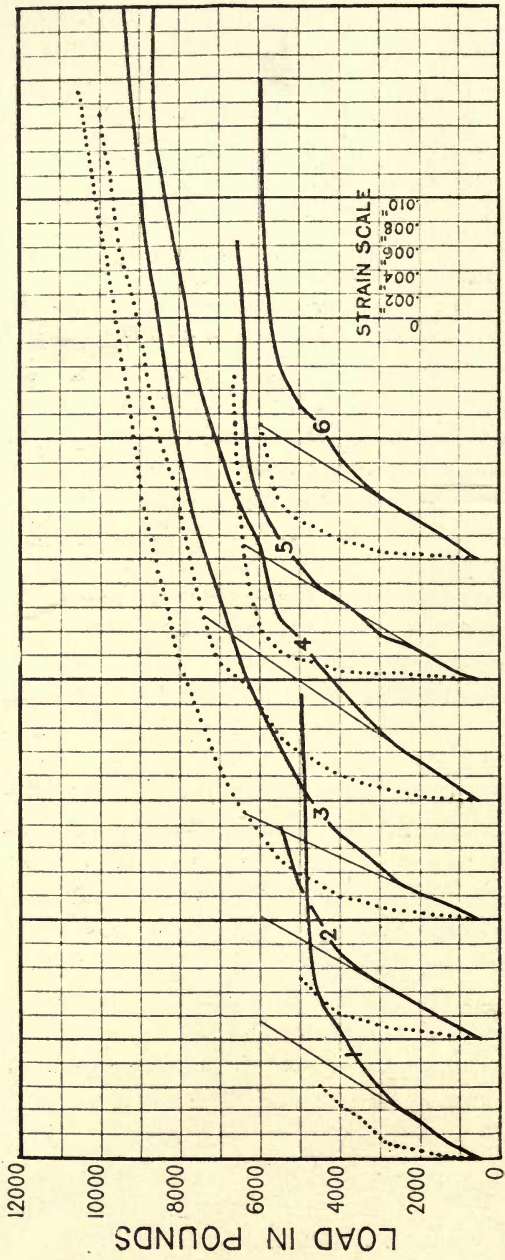


TABLE XIX

APPLIED LOADS AND CORRESPONDING WITHDRAWALS AND SETS OF THREE KINDS OF SPIKES INSERTED IN A CREOSOTED YELLOW PINE TIE

	Cut Spike Driven 5½ Inches into ½-inch Hole				Screw Spike Screwed 6 Inches into 5/8-inch Hole				Sessler Grip Spike Driven 5½ Inches into 7/16-inch Hole			
Applied Load	Withdrawal	Set	Withdrawal	Set	Withdrawal	Set	Withdrawal	Set	Withdrawal	Set	Withdrawal	Set
500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1000	.0008	.0000	.0009	.0002	.0008	.0004	.0009	.0002	.0006	.0002	.0010	.0002
1500	.0018	.0003	.0019	.0006	.0015	.0004	.0022	.0003	.0015	.0003	.0020	.0003
2000	.0030	.0008	.0028	.0007	.0020	.0005	.0031	.0004	.0023	.0004	.0030	.0004
2500	.0040	.0013	.0039	.0009	.0030	.0008	.0043	.0009	.0033	.0004	.0040	.0007
3000	.0060	.0018	.0047	.0011	.0046	.0010	.0058	.0011	.0038	.0005	.0052	.0010
3500	.0080	.0035	.0059	.0018	.0059	.0018	.0077	.0013	.0055	.0005	.0069	.0014
4000	.0108	.0043	.0072	.0021	.0071	.0019	.0092	.0021	.0067	.0007	.0084	.0021
4500	.0130	.0062	.0097	.0036	.0089	.0030	.0113	.0029	.0077	.0013	.0109	.0036
5000			.0130	.0052	.0116	.0038	.0134	.0036	.0097	.0016	.0127	.0047
5500					.0145	.0052	.0151	.0050	.0113	.0022	.0162	.0069
6000					.0177	.0073	.0213	.0079	.0147	.0042	.0411	.0295
6500					.0217	.0096	.0243	.0098				
7000					.0270	.0126	.0292	.0130				
7500					.0320	.0168	.0354	.0169				
8000					.0390	.0211	.0439	.0248				
8500					.0498	.0285	.0542	.0301				
9000					.0620	.0359	.0667	.0391				
9500					.0778	.0467	.0771	.0461				
10000					.0930	.0576	.0921	.0568				
Ultimate load in pounds	4940		5600			11500		11500		6400		6000
Elastic withdrawal limit in pounds	2600		3300			2600		2700		4600		3000
Ratio $\frac{\text{E. W. L.}}{\text{U. L.}}$ =	.527		.589			.226		.255		.719		.500

TABLE XX

EFFECT OF REPEATED APPLICATION OF 3000 LBS. PULL UPON THE THREE TYPES OF SPIKES TESTED CREOSOTED YELLOW PINE TIE

	Cut Spike Driven 5½ Inches into ½-inch Hole		Screw Spike Screwed 6 Inches into 5/16-inch Hole		Sessler Grip Spike Driven 5½ Inches into 7/16-inch Hole	
No. of Applications	Strain in Inches	Set in Inches	Strain in Inches	Set in Inches	Strain in Inches	Set in Inches
1	.0046	.0000	.0039	.0000	.0041	.0000
2	.0047	.0000	.0039	.0002	.0041	.0001
3	.0048	.0004	.0039	.0001	.0046	.0003
4	.0048	.0004	.0039	.0001	.0049	.0004
5	.0048	.0006	.0039	.0002	.0051	.0004
6	.0055	.0008	.0039	.0001	.0051	.0005
7	.0048	.0008	.0048	.0003	.0053	.0005
8	.0055	.0009	.0048	.0002	.0053	.0006
9	.0055	.0009	.0049	.0003	.0051	.0006
10	.0056	.0010	.0049	.0002	.0053	.0006
11	.0056	.0008	.0049	.0003	.0053	.0007
12	.0056	.0009	.0048	.0004	.0053	.0007
13	.0056	.0010	.0049	.0003	.0053	.0008
14	.0057	.0011	.0048	.0003	.0053	.0007
15	.0057	.0011	.0049	.0003	.0053	.0008
16	.0057	.0012	.0050	.0002	.0061	.0008
17	.0058	.0012	.0049	.0002	.0054	.0009
18	.0058	.0013	.0050	.0002	.0059	.0009
19	.0059	.0013	.0049	.0003	.0059	.0009
20	.0058	.0013	.0049	.0003	.0060	.0009
21	.0058	.0013	.0051	.0003	.0060	.0009
22	.0058	.0013	.0049	.0003	.0060	.0009
23	.0058	.0013	.0050	.0003	.0060	.0009
24	.0058	.0013	.0049	.0003	.0062	.0010
25	.0058	.0014	.0056	.0004	.0063	.0010
26	.0059	.0015	.0049	.0005	.0062	.0010
27	.0058	.0015	.0049	.0006	.0064	.0010
28	.0059	.0015	.0050	.0005	.0063	.0010
29	.0059	.0015	.0049	.0004	.0063	.0011
30	.0060	.0015	.0050	.0005	.0064	.0011
Initial set on application of preliminary load of 3000 lbs.		.0003		.0005		.0007

Sets are recorded at loads of 500 lbs.

The behavior of the screw spike as already mentioned is somewhat peculiar, at about 2700 lbs. the true elastic limit is reached, evidently due to a bearing failure of the thread upon the wood, represented by the lower percentage in the above table. From this point up to about 5000 lbs. the load strain curve is still substantially straight, but slightly more inclined. At this upper limit, represented by the higher value in the above table there is a decided change in direction increasing rapidly with the load, practically a yield point. Because of the limited extent of this investigation covering two spikes of each kind in one tie only, the results cannot be considered conclusive and require further verification.

To obtain additional data as to the elastic behavior of a spike in a tie, one spike of each type inserted in a creosoted yellow pine tie was subjected to thirty applications of loads varying between the limits of 500 and 3000 lbs. and the withdrawal and set for each load recorded. In each case the spike was subjected to an initial load of 3000 lbs. and the reading of the Ames dial when the load was reduced to 500 lbs. was taken as zero set. The upper limit of 3000 lbs. was selected because this represented approximately the elastic withdrawal limit of a cut spike in such a tie. The results of these tests are given in Table XX.

This table shows that under thirty applications of 3000 lbs. the final set amounted to .0005 of an inch for the screw spike, .0011 of an inch for the Sessler Grip spike, and .0015 of an inch for the cut spike. The screw spike showed slightly lower elastic withdrawals and permanent sets than either the cut or the Sessler Grip Spike.

REPULLING TESTS

The average ultimate resistance of each type of spike tested under each of the conditions of driving and tie are given below for the first, second and third withdrawals of ¼-inch, respectively.

Standard Cut Spike—Pennsylvania R. R. Lines West
Ultimate Resistance to Withdrawal in Pounds

Withdrawal	Method of Driving	Kind of Tie			
		Chestnut	Treated Yellow Pine	White Oak	Douglas Fir
1	Without hole	5310	4120	9720	4530
2	Without hole	4180	3510	8580	3500
3	Without hole	4090	3080	7590	3350
	Per Cent. loss on second withdrawal	21.2	14.8	11.7	22.8
	Per Cent. loss on third withdrawal	23.0	25.2	21.9	26.0
1	Into ½-inch hole	5210	4980	9400	3890
2	Into ½-inch hole	3930	3600	7710	3290
3	Into ½-inch hole	3740	3680	7150	2480
	Per Cent. loss on second withdrawal	24.6	27.8	18.0	15.4
	Per Cent. loss on third withdrawal	28.2	26.2	23.9	36.3

Standard Screw Spike—Delaware, Lackawanna and Western R. R.
Ultimate Resistance to Withdrawal in Pounds

Withdrawal	Method of Driving	Kind of Tie			
		Chestnut	Treated Yellow Pine	White Oak	Douglas Fir
1	Screwed in ⅝-inch hole	10020	6340	14740	7910
2	Screwed in ⅝-inch hole	9930	6460	14530	8020
3	Screwed in ⅝-inch hole	9260	6440	13400	6540
	Per Cent. gain or loss on second withdrawal	−1.0	+1.8	−1.4	+1.4
	Per Cent gain or loss on third withdrawal	−7.6	+1.6	−9.1	−17.3
1	Driven 4½ inches and screwed 1½ inches in ⅝-inch hole	8220	7800*	11620	6440
2		8310	8500*	12960	6600
3		7020	8650*	12930	5260
	Per Cent. gain or loss on second withdrawal	+1.1	+9.0	+11.4	+2.4
	Per Cent. gain or loss on third withdrawal	−14.6	+10.8	+11.3	−18.3

Sessler Grip Spike—American Spike Company
Ultimate Resistance to Withdrawal in Pounds

Withdrawal	Method of Driving	Kind of Tie			
		Chestnut	Treated Yellow Pine	White Oak	Douglas Fir
1	Without hole	7780	4700	11390	4680
2	Without hole	5640	3750	9940	3710
3	Without hole	5350	3360	9080	3370
	Per Cent. loss on second withdrawal	27.5	20.2	12.8	20.8
	Per Cent. loss on third withdrawal	31.2	28.5	20.2	28.0
1	Into 7/16-inch hole	6240	5910	11940	5570
2	Into 7/16-inch hole	4360	4680	9590	4260
3	Into 7/16-inch hole	3880	3800	8690	3630
	Per Cent. loss on second withdrawal	30.2	20.8	19.8	23.6
	Per Cent. loss on third withdrawal	37.8	35.7	27.3	34.0

* Loads at practically 0.250 inches withdrawal.

The effects of redriving a spike as indicated by the per cent. loss in resistance to withdrawal is of importance in the design of a track fastening insofar as the elastic holding power is reduced thereby. As previously stated no track fastening should be subjected to load in excess of its "elastic withdrawal limit". A withdrawal of ¼-inch could be caused only by loads considerably in excess of this amount or by deterioration of the wood fibres resulting in the gradual withdrawal of the spike after a large number of applications of load, even though this load was originally well below the elastic withdrawal resistance.

The curves shown on Plates XV to XXII, indicate that the screw spike is affected in its elastic holding power to a considerably greater extent than either the cut or Sessler Grip spikes. This comparison may be more clearly shown when the curves representing the three withdrawals of a given type of spike are superimposed.

The effect of redriving upon the elastic withdrawal resistance of the cut and Sessler Grip spike appears to be no greater (possibly less) than the effect upon the ultimate resistances. The true effects of redriving upon the elastic behavior of the spikes have not been determined by the more refined method described under the auxiliary tests made for direct pull resistance and consequently conclusions upon these effects must be tentative awaiting subsequent tests.

Attention is also called to the fact that the ties used in the repulling tests were stored for approximately three weeks prior to the tests at room temperature, whereas those used in the direct pulling tests were subjected to similar conditions for a few days only.

GENERAL CONCLUSIONS

1. The tests outlined herein, although of limited extent, show conclusively that the rail fastenings tested act as elastic structures within certain limits depending upon the character of the wood and type of spike.

2. In the softer woods the elastic limit of the fastening is reached at very small withdrawals ranging from 0.004 to 0.006 inches. In an oak tie these limits appear to be somewhat higher.

3. Within the elastic range of the fastening the resistance developed by the fastening is directly proportional to the amount of withdrawal.

4. Small permanent withdrawals or sets have been recorded within the elastic range of the rail fastening but these are no greater than would be reasonably expected in a material such as wood.

5. A rail fastening to approach permanency must at no time be stressed beyond its elastic holding power, making due allowances for the fatigue and physical deterioration of the wood fibres during the life of the fastening.

6. In view of the importance of these facts to the railway profession a more complete investigation should be made to definitely establish the elastic behavior of various types of spikes, both without and with preformed holes of various sizes driven into ties of various stages of deterioration.

The Testing Laboratory desires to express its appreciation for the courtesy and co-operation in this investigation of the following gentlemen:

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